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STORAGE STABILITY OF CIVIL DEFENSE SHELTER RATIONS

(ANNUAL REPORT)

by
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UNIVERSITY OF GEORGIA

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DIVISION OF
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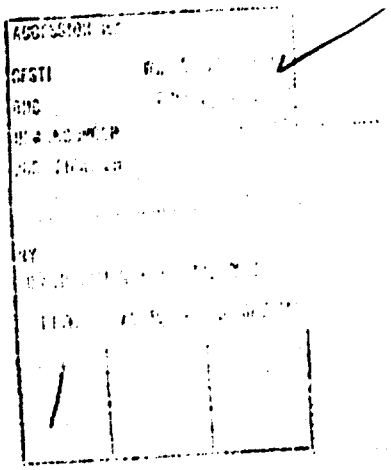

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Division of Food Science
University of Georgia College of Agriculture Experiment Stations
GEORGIA EXPERIMENT STATION
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FOREWORD

This is the sixth annual report of a study which was initiated in 1962 to determine the stability of representative types of Civil Defense shelter foods and their containers when stored for extended periods. The first five reports, of which the fifth was Technical Report 68-26-GP, December 1967, were issued by U.S. Army Natick Laboratories, Natick, Massachusetts 01760.

The work reported through 1967 was performed under Contract DA19-129-QM-2050 (project reference OCD-05-62-156), 21 June 1962 - 20 June 1967, awarded by the U.S. Army Natick Laboratories to the University of Georgia, Georgia Experiment Station, to provide facilities and collect data for the study. The purpose was to simulate conditions likely to exist in warehouses and selected shelters in which, beginning in 1962, large quantities of food were stored under the Civil Defense Shelter Program. This included types of food not previously procured, representing new formulations, processes and containers on which little or no long-term storage information was available.

Continuation of the study under the current subcontract, awarded by Stanford Research Institute, the lead laboratory of the Office of Civil Defense, will extend storage into 1969 when the stock of rations stored for the project will be practically exhausted or will have fallen below the acceptable range of quality. Project Officer for this subcontract is Dr. James F. Halsey, Civil Defense Technical Office, Stanford Research Institute.

Sam R. Cecil
Food Scientist
Georgia Experiment Station

APPROVED:

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ABSTRACT

Results are reported on the stability of ten lots of fallout shelter cereal rations stored for 5 years and 3 lots of carbohydrate supplement stored for 4 years at 100°F/30% r.h., 100°/57%, 70°/80%, 70°/57%, 40°/57%, and 0°/ambient r.h. Rations include 4 lots of survival crackers, 4 lots of survival biscuits, 2 lots of bulgur wheat wafers, and 3 lots of mixed lemon and cherry flavored hard candies. Data include 60-month and 43-month values, respectively, for (1) bursting strength, moisture content, and general conditions of V3c fiberboard cases; (2) residual oxygen, leaking, corrosion, and coating defects of 2½-gallon and 5-gallon metal cans; (3) breakage and general condition of package seals, seams, materials, and product units; (4) fracture strength, peroxides, and free fatty acids of wheat products; (5) pH and sugar contents of carbohydrate supplements; and (6) moisture content, color, sensory quality, and hedonic ratings for all products. Results of previous examinations of stored rations are discussed.

STORAGE STABILITY OF CIVIL DEFENSE SHELTER RATIONS
(ANNUAL REPORT)

Introduction

A storage study was conducted over a five-year period to determine the stability of representative types of Civil Defense shelter rations. At the beginning of this period, 10 cereal items were deposited in storage over an interval of four months, and 3 carbohydrate supplements were stored about a year later. Determinations were also made of the stability of packaging materials in which the rations were stored.

Items stored for 5 years were:

Crackers code	Contract number	Biscuit code	Contract number	Bulgur Wafers code	Contract number
CD1	2692-62	CD2	2686-62	CD9	2254-62
CD3	2689-62	CD4	2694-62	("white" wheat)	
CD5	2687-62	CD6	2688-62	CD10	
CD8	2691-62	CD7	2687-62	("red" wheat)	

Carbohydrate supplements, stored 4 years, were:

Code	Contract Number
CD11	24018-63
CD12	24016-63
CD13	24023-63

Storage conditions for the period, November 1966 to March 1968, were:

Code	Temperature °F	Relative Humidity percent
100/80	100.1, +1.6, -0.6	79.7, +1.7, -4.9
100/57	99.9, +2.3, -1.5	57.2, +1.3, -2.7
70/80	69.9, +0.2, -0.8	79.4, +1.4, -5.5
70/57	70.1, +1.4, -0.7	57.5, +3.8, -1.0
40/57	40.2, +5.3, -0.8	58.5, +3.6, -2.2
0/ambient	-0.4, +2.5, -1.0	ambient (high)

The large deviations resulted from defective humidity control equipment in the 100/80 and 70/80 rooms and temperature control equipment in rooms 70/57 and 40/57, including the off periods required to replace the defective units.

Samples withdrawn for examination at the end of the respective five-year or four-year periods consisted of one case and two cans from each of the six

storage conditions for each item. Basic procedures and sample replicates for the various observations and determinations included in the examinations are given with the results and data reported below. Statistical treatment of data employed standard procedures for analysis of variance, multiple range testing for significance, and calculation of simple correlation coefficients.

Methods and Results

I. Fiberboard (V3c) Cases

Entire cases were used in all examinations excepting those for biscuit CD4 and crackers CD3 and CD1. These three items were packed in 2½-gallon cans, six cans per case, and only 1/3 case was available for each withdrawal from storage. Samples at 60 months for CD1 were from intact cases, while those for CD3 and CD4 were the second 1/3 of cases opened at 48 months.

Ten 4-inch squares were cut from available locations on side and end panels of each case and placed in sealed containers before removal from the storage room. Containers were then removed to a 73°F condition, allowed to equalize at this temperature, and bursting strength determined as rapidly as possible after opening the container, using a manually operated Mullen-type tester.

1. Bursting strength (Table 1)

Although cereal item cases decreased sharply in bursting strength at 100°F and moderately at 70°F during the first 4 years of storage, with moderate increases at 40° and 0°, there was relatively little change from 48-months values during the fifth year. Carbohydrate supplement cases decreased moderately at 70°F and increased somewhat at 40° during the fourth year. Mean changes from initial bursting strength values were as follows:

Condition °F/% r.h.	Cereal item cases stored 5 years 6-can; CD1, 3, 4	2-can cases	Supplement cases stored 4 years 2-can cases
100/80	-186	-154	-80
100/57	-158	-125	-88
70/80	- 69	- 33	-11
70/57	- 32	12	-44
40/57	59	48	57
0/amb	72	41	- 9

Of the 26 cases from 100°F, all except CD8 (5 years) and CD11 (4 years) were below 400 psig; 6 were below 300, averaging 275. Eight of the cases from 70° were below 400, averaging 384. As seen in Table 1, values averaged lower at 80% r.h. than at 57% (17 of 20 sets) in the 100° and 70° rooms, but there was no significant correlation of moisture with bursting strength within rooms.

TABLE 1

BURSTING STRENGTH OF V3c FIBERBOARD
(pounds per square inch)

A. Cereal Item Cases Stored 60 Months

Condition °F/% r.h.	CD1	CD3	CD4	CD2	CD5	CD6	CD7	CD8	CD9	CD10	Mean	Std.dev. 10 reps
Initial	485	434	507	451	405	472	483	535	498	463	473	33
100/80	317	271	281[a]	269	366	331	309	408[a]	272	271	309	19
100/57	316	303[a]	334	308	356	366	344	419	319	319	338	26
70/80	396	434[a]	488[a]	462	365	476	479	517[a]	377	398	439	30
70/57	401	438[a]	491	504	434	475	493	528	474	477	472	31
40/57	525[a]	503	575	535	415	476	560	626[a]	532	540	528	45
0/amb	500[a]	497[a]	644	562	397	494[a]	552	620	505	502	527	45
std.dev.,10 reps	44	24	31	30	27	32	30	30	42	44	34	—
sign.dif., 5%	40	21	28	27	25	29	27	27	38	40	10	31[b]
Mean	409	408	469	440	389	436	456	520	413	418	436	13[c]

B. Carbohydrate Supplement Cases Stored 48 Months

	CD11	CD12	CD13	Mean	Std.dev. 10 reps
Initial	548	365	426	446	37
100/80	438	301	358	366	31
100/57	455	283	336	358	23
70/80	513	394	398	435	40
70/57	427[a]	354	424	402	25
40/57	603	470	437	503	37
0/amb	450[a]	432	427	437	51
std.dev.,10 reps	46	31	28	36	—
sign.dif., 5%	41	28	25	19	35[b]
Mean	481	372	397	417	13[c]

[a] Manufacturer's case code different from that of initial case.
[b] Significant difference for items in rooms.
[c] Significant difference for item means.

2. Moisture Content (Table 2)

Samples for moisture determinations were obtained at the same time and in the same manner as those for bursting strength. Moisture was calculated from weight losses of 5 grams of chopped fiberboard after heating 5 hours at 100°C under a 29-inch vacuum.

Moisture contents as given in Table 2 averaged 0.53% lower for cereal item cases, and 0.47% lower for supplement cases at 100° and 70°, than those for the preceding year. Supplement cases at 40° and 0°F averaged 0.28% higher. These changes, relatively unimportant when compared with moisture differences associated with storage conditions, apparently resulted from minor variations in adjustments of room equipment and room loading.

In general, moisture contents increased in proportion to relative humidity, but equilibrium levels were lower at higher temperatures, apparently as a result of increased vapor pressure differentials. There was no serious damage to the cases from the higher moisture contents, although slight decreases in bursting strength and increases in tendency to mold and to bulge in the stacks were observed.

3. General Conditions of Cases

All the cases showed more or less evidence of staining and slight wear from handling in storage rooms which were also in use for other commodities. The resulting "slightly used" appearance, however, had little influence on their function as containers for the ration cans. Certain of the minor imperfections observed during the most recent examinations are given below; ratings for extent, where given, are on a 9-point scale.

Loose Seals. Although the adhesive holding the case flaps has become noticable "set" and in some instances slightly "cracked" in cases stored at the higher temperatures, there has been no evidence of loosening of flap seals with storage. Inadequate spreading of the adhesive, leaving loose edges of flaps, was observed in 64 of the 90 cases examined from CD5 and CD7 (mean defect rating 0.4), 28 of 84 cases of CD10 and CD11 (mean rating 0.5), and in 22 cases (mean rating 0.5) of all other items except CD2, CD6 and CD12. Also, staples have become quite rusty in some of the cases at 100°/80% and 70°/80%, but neither slightly frayed flap edges nor rusty staples has impaired the usefulness of the cases for storage.

Delamination. With the exception of the frayed loose flap edges noted above, only 12 of 580 cases examined during the 5 years had delaminated area: 6 of flaps and 6 of panels. Mean defect rating for delaminated flaps was 1.4, and these were observed from the first through fifth years, 2 flaps each at 100°, 40° and 0°F, apparently resulting from handling of cases during transfer or restacking in the storage rooms. Panel delaminations, 1 at 2 years, 2 at 3 years, 3 at 5 years, were all at 80% r.h., 5 at 70° and 1 at 100°F; mean defect rating was 2.5. These included 1 case each of CD6 and CD3, but 2 cases each or about 11% of all the cases of CD1 and CD4. Both of the delaminations in CD4 and 1 of the 2 in CD1, however, were in cases which had been cut in the preceding year, so these panel separations probably resulted from absorption of moisture through the cut edges of the board.

TABLE 2

MOISTURE CONTENT OF V3c FIBERBOARD
(percent)

A. Cereal Item Cases Stored 60 Months

Condition °F/% r.h.	CD1	CD3	CD4	CD2	CD5	CD6	CD7	CD8	CD9	CD10	Mean
100/80	11.0	10.8	10.6	10.8	11.1	10.6	10.8	10.7	10.6	10.7	10.77
100/57	7.6	7.5	7.4	7.3	7.6	7.5	7.5	7.4	7.5	7.5	7.48
70/80	11.4	11.6	11.4	11.5	11.5	11.4	11.6	11.1	11.2	11.3	11.40
70/57	7.7	7.9	7.4	7.5	7.4	7.4	7.5	7.3	7.6	7.6	7.52
40/57	8.9	8.9	8.6	8.7	8.9	8.7	8.7	8.8	8.8	8.9	8.77
0/amb	14.2	14.3	14.6	14.7	15.1	13.6	14.7	14.3	13.8	13.7	14.23
std.dev., 2 reps	.04	.05	.05	.05	.04	.03	.03	.03	.03	.05	.04
sign.dif., 5%	.08	.13	.11	.12	.10	.07	.06	.07	.06	.13	.03
Mean[a]	10.12	10.15	9.99	10.08	10.18	9.85	10.15	9.93	9.90	9.93	10.03

B. Carbohydrate Supplement Cases Stored 48 Months

	CD11	CD12	CD13	Mean
100/80	10.9	10.6	10.7	10.72
100/57	7.9	7.4	7.7	7.67
70/80	11.2	10.9	10.8	10.95
70/57	7.7	7.5	7.6	7.55
40/57	9.5	9.3	9.4	9.40
0/amb	14.5	13.5	14.7	14.04
std.dev., 2 reps	.10	.04	.07	.08
sign.dif., 5%	.25	.10	.15	.09
Mean[b]	10.27	9.87	10.03	10.05

[a] Significant differences were 0.17% for item means, 0.09% for items in rooms.
[b] Significant differences were 0.13% for item means, 0.16% for items in rooms.

Mold. The only mold observed on the outside of the cases examined during the current storage year was 2 small areas (rating of 0.25) on supplement cases CD13 from 80% r.h. conditions. At previous examinations similar moldy areas were seen on 25% of the cases stored at 70°/80% (mean rating 0.7) and 5% of those from 100°/80% (rating 0.7). Lightly molded spots were found inside the CD5 case and the CD13 case from 100°/80% (ratings 2.0 and 0.8). Previously observed inside mold averaged 0.6 rating in 20% of the cases from 80% and 0.4 rating in 5% of the cases from 57% r.h. rooms. Thus there was no indication of increased incidence of molding beyond the second to fourth year, when most of it was obserbed. Practically all moldy areas were on outer or inner surfaces which had been in contact with other case or can surfaces.

Sweating of Cases. Average rating for moisture or other staining of the outside surfaces of cases was 0.80, exactly the same as the mean high rating from previous years. By storage conditions, average ratings were 1.26 for 70°/80%, 0.94 for 100°/80%, 0.85 for 70°/57%, 0.75 for 100°/57%, and 0.50 for the 40° and 0°F rooms. None of the staining was severe enough to interfere with furtner utility of the cases.

Inside sweating of cases was judged almost entirely from stained areas resulting from corrosion of cans where they were in contact with case surfaces, so sweating of cases and cans were evaluated together. Sweating varied considerably with density of the packs. Items CD1, 3, 4 (8 lb. cans, averaged 5 per case) and CD2, 5, 7, 8 (13-15 lb. cans, 2 per case) had average ratings ranging 0.46-0.80, mean 0.70; CD6 with 2x18 lb. cans averaged 0.96, CD9 and 10 with 2x32 lb. cans averaged 1.49, while CD11, 12, 13 with 2x35lb. cans, but only 4 years in storage, averaged 1.20. Ratings were somewhat higher in some of the cases stored on the bottom of 4-case stacks, but high ratings were not confined to either bottom or 2nd-from-bottom positions. By storage conditions, ratings averaged 1.56 from 70°/80%, 1.29 from 100°/80%, 0.80 from the 57% rooms at 70° and 100°, and 0.65 from the 40° and 0°F rooms. General mean rating for inside sweating and staining from cans was 0.88 for the current examinations, as compared to a mean high rating of 0.78 from previous years. While not serious from the standpoint of utility of the cases, this does indicate some increase in corrosion of the cans.

Collapse. Ratings for collapse have been relatively variable throughout the storage period, as some cases were wrinkled or dented in shipment (these were generally used during the first year or two) and none of the stacks have been more than 5 cases high. As bulging or wrinkling of cases, ratings for cereal items averaged 0.70 through 4 years, 0.43 at 5 years. Supplement cases averaged 1.00 through three years, 1.12 at 4 years. Storage conditions made little difference during the last year, 80% conditions averaging 0.65, 57% conditions 0.57, the 0°F room 0.50. Can and case weights had some influence, cracker and biscuit cases at 39 lbs. having average rating of 0.38, wafer cases at 71 lbs. averaging 0.63, and supplement cases at 78 lbs. averaging 1.12 as noted above. Actually this storage study provides no test of collapse, as ration stocks in various shelters have been observed in stacks twice as high as the experimental rooms will allow.

4. Condition of Case Markings

There has been essentially no change in the printing on the ration cases. At the current examination, fading was rated 0.27 at 100°F and 70°/80%, 0.19 at 70°/57% and the two lower temperatures. Previous high ratings for fading averaged 0.31. Blurring of print averaged 0.42 at 100°, 0.47 at 70°, and 0.36 at 47° and 0°F; previous high ratings averaged 0.52. Thus there was no indication of any tendency for case markings to become illegible.

II. Metal Cans

Cans of items CD1, 3 and 4 were 2½-gallon size, containing approximately 7 lbs. of crackers or biscuits. All other cans were 5-gallon size, containing 12½ - 18½ lbs. of crackers or biscuits (CD2 and 5-8), 32-33 lbs. of bulgur wafers (CD9, 10), or 34-36 lbs. of carbohydrate supplement. All samples consisted of two cans each.

1. Residual Oxygen in Cans. (Table 3)

Oxygen remaining in the can space was determined as the lowest reading obtained while passing gases from the can through a direct-reading oxygen analyzer adjusted to a fresh air reading of 20.9% by volume. Determinations were made only for cereal items, CD1-10.

Oxygen in non-leaking cans decreased during the fifth year in all storage conditions (though not in every can of each item) except 0°F. Previous low non-leakers and periods when they were observed, and non-leakers and leakers at 5 years, averaged as follows:

Condition °F/% r.h.	Previous Low Values			Values at 5 Years	
	months		mean	non-leakers	leakers
	range	mean	%	%	%
100/80	18-48	36	6.3	4.0	9.4
100/57	18-48	36	5.3	3.2	12.0
70/80	18-48	42	9.5	8.3	12.9
70/57	24-48	42	11.6	8.9	14.3
40/57	36-48	45	13.9	13.0	16.2
0/amb	24-48	42	16.9	17.6	20.2

As seen in Table 3, residual oxygen was below 5% in some cans of crackers and biscuits at 100° and 70°F, and below 10% in many. Wafer CD9 averaged only 2.1% at all temperatures above 0° and CD10 averaged 2.6% at 100° and 70°, 6.9% at 40°. The fact that oxygen in 14 of the cans which were classed as non-leakers averaged 2.2% higher than similar cans on previous examinations suggests that there has possibly been some slight leaking in cans whose seals subsequently "closed up" -- this is not an extremely unusual phenomenon in double-seam cans subjected to sharp changes in temperature. Otherwise, depletion of canspace oxygen continued to be progressive with time, temperature, and the amounts of rations in the cans.

TABLE 3

RESIDUAL OXYGEN IN CANS OF CEREAL ITEMS STORED 60 MONTHS
(percent by volume)

Condition	Crackers				Biscuits				Wafers		Mean	Std.dif.
°F/% r.h.	CD1	CD3	CD5	CD8	CD2	CD4	CD6	CD7	CD9	CD10		cans
Initial	19.3	20.1	19.7	20.4	20.1	20.4	17.8	20.4	16.6	17.0	19.18	0.28
100/80	11.6[a]	6.3	3.2	6.9[a]	5.6	17.7	1.9	4.8	3.2	2.9	6.43	1.64
100/57	12.6[a]	7.3	2.9	4.3	2.2	18.4	2.6	3.9	1.8	2.6	5.86	2.55
70/80	8.6	10.3[a]	6.9	11.2	14.2	19.2	9.1	14.4	0.3	2.3	9.65	1.73
70/57	10.4	8.3	5.7	10.8	14.4	19.6	16.0[b]	15.2	3.6	2.5	10.65	1.84
40/57	14.3	13.8	14.3	16.5	17.1	20.1	14.3[a]	19.3	1.8	6.9	13.84	2.91
0/amb	17.6	17.5[a]	18.2	19.0	19.9	20.6	17.4	20.2	14.7	14.7	17.98	1.42
std.dif.,cans	1.35	2.07	.40	1.93	1.23	2.39	2.70	1.67	1.40	3.77	2.09	----
sign.dif., 5%	2.34	3.63	.69	3.33	2.13	NS	4.81	2.90	2.43	6.52	.94	3.30[c]
Mean	12.54	10.58	8.53	11.46	12.07	19.27[b]	10.21	12.96	4.25	5.32	10.73	1.26[d]

[a]Both cans were questionable leakers. Single leakers, omitted except in can standard difference values, averaged 3.6 ± 2.1 higher than duplicate non-leakers.
[b]All cans were leakers.
[c]Significant difference for items in rooms.
[d]Significant difference for item means.

TABLE 4

LEAKING CANS
(as percentage of cans examined)

Items CD	Definite Leakers				Questionable Leakers[a]			
	0-18 mo.	24-36 mo.	48-60 mo.	total	0-18 mo.	24-36 mo.	48-60 mo.	total
(2½-gal)								
1	4.9	16.7	.0	6.74	2.4	12.5	20.8	10.11
3	7.3	16.7	20.8	13.48	4.9	4.2	16.7	7.87
4	39.0	83.3	100.0	67.42	34.1	.0	.0	15.73
(5-gal)								
2	.0	.0	.0	.00	2.4	4.2	12.5	5.62
5	12.2	4.2	8.3	8.99	2.4	12.5	.0	4.49
6	17.9	41.7	20.8	25.29	2.6	4.2	25.0	9.20
7	.0	4.2	.0	1.12	4.9	.0	4.2	3.37
8	.0	.0	.0	.00	.0	4.2	12.5	4.55
9	.0	4.2	.0	1.12	.0	4.2	4.2	2.25
10	.0	.0	.0	.00	.0	.0	12.5	3.37
(5-gal)	0-18 mo.	24-36 mo.	48 mo.	total	0-18 mo.	24-36 mo.	48 mo.	total
11	12.2	4.2	16.7	10.39	12.2	.0	8.3	7.79
12	2.4	.0	25.0	5.19	2.4	.0	33.3	6.49
13	12.2	.0	.0	6.49	4.9	.0	.0	2.60
Condition °F/% r.h.	6-18 mo.	24-36 mo.	48-60 mo.[b]	total	6-18 mo.	24-36 mo.	48-60 mo.[b]	total
100/80	3.8	11.5	13.0	8.52	10.3	3.8	21.7	11.36
100/57	7.7	9.6	10.9	9.09	3.8	3.8	13.0	6.25
70/80	10.3	19.2	13.0	13.64	3.8	.0	6.5	3.41
70/57	7.7	13.5	17.4	11.93	5.1	5.8	4.3	5.11
40/57	11.5	9.6	21.7	13.64	5.1	3.8	10.9	6.25
0/amb	9.0	17.3	13.0	12.50	6.4	3.8	10.9	6.82
total	8.33	13.46	14.86	11.36[c]	5.77	3.53	11.23	6.44[c]

[a]Cans which either leaked very slowly in test, or had internal evidence of having leaked sometime, but did not leak on test.
[b]Cereal items only at 60 months.
[c]Includes initial leakers.

2. Leaking Cans (Table 4)

Leaks were detected as streams of bubbles when cans at 73°F were immersed 2 minutes in water at 103-105°F; questionable leakers were those cans emitting only a few bubbles, but whose oxygen, moisture or rancidity values indicated that leaking had probably occurred.

During the fifth year, biscuit CD2, cracker CD8 and wafer CD10 remained free of definite leaks, but 25% of the cans in each of these items were listed as questionable leakers. Cracker CD1, biscuit CD7 and wafer CD9 also had no definite leaks, although some had been previously recorded, and each also increased somewhat in questionable leakers. Cracker CD5 had no leakers at 5 years, but had some previously. Biscuit CD6 remained about the same in leakers but increased in questionable leakers, while cracker CD3 increased in both types of leakers, and biscuit CD4 again leaked in every can as at 4 years.

Among supplement cans stored 4 years, leakers and questionable leakers increased in CD11 and CD12, but CD13 has had no leakers since the examination at 18 months. Thus the general pattern was one of gradual increase in leaking (excepting CD13), the latest examination including 16.4% leakers and 21.6% questionable leakers, representing increases in questionable leakers at every condition and in definite leakers at every condition except 0°F. As seen in Table 4, leakers observed during the entire study now amount to 11.36%, questionable leakers to an additional 6.44%, or almost one can in each five cans examined.

3. Corrosion of Cans (Tables 5 and 6)

External. There was little general increase in external corrosion of cereal item cans during the fifth year, although ratings averaging about 0.5 above previous highs were received by 2½-gallon cans of CD4 and 5-gallon cans of CD2, 5, 8 and 10 at the 80% r.h. conditions. Carbohydrate supplement cans stored 4 years also averaged higher than previously, by 0.8 at 100°/80% and 0.3 at 70°/80%, but with the exception of a 1.6 increase in CD13 at 70°/57%, other ratings were lower. Average trends for the values given in Tables 5 and 6, as changes from previous high ratings, were as follows:

	100°		70°		40°	0°	Period
	80%	57%	80%	57%	57%	amb.	Mean
cereal, 2½-gallon	-.37	-.40	-.20	-.07	-.30	-.23	-.03
cereal, 5-gallon	-.31	-.03	-.06	+.15	-.20	-.19	+.19
supplement, 5-gallon	+.80	-.05	+.30	+.23	-.73	-.60	+.34

Thus, while rusting has become fairly extensive on some of the seams and panels of the cans at the higher humidities, much of it occurred during the earlier periods of storage. Through the latest examination, no can has been observed in which leaking could be attributed to corrosion.

TABLE 5

CORROSION OF CEREAL ITEM CANS STORED 60 MONTHS
(0-9 scale, 0 = none)

Condition	2½-gallon type					5-gallon type								
°F/% r.h.	CD1	CD3	CD4	Mean	Std.dif. cans	CD2	CD5	CD6	CD7	CD8	CD9	CD10	Mean	Std.dif. cans
External, pitted:														
Initial	0.0	.2	.3	.17	.17	0.0	.4	.5	.3	.3	.5	.5	.36	.36
100/80	.8	1.0	2.0	1.27	.33	2.9	3.3	3.4	3.7	3.7	3.8	4.1	3.56	..26
100/57	.3	.4	.9	.53	.20	1.3	1.1	1.4	1.5	1.6	2.6	1.5	1.57	.51
70/80	1.1	.8	1.8	1.23	.26	2.8	2.0	2.4	1.9	1.4	3.1	3.0	2.37	.60
70/57	.1	.6	1.1	.60	.12	.8	2.0	1.0	1.5	.5	.9	1.1	1.11	.36
40/57	.1	.3	.7	.37	.17	.6	1.3	.8	.5	.5	.8	1.5	.86	.61
0/amb	.2	.1	.6	.30	.24	.5	.9	1.0	.7	.7	1.1	.9	.83	.28
std.dif., cans	.12	.20	.32	.23	----	.41	.70	.46	.61	.29	.29	.25	.46	----
sign.dif., 5%	.21	.35	.56	.20	.14[a]	.73	1.21	.79	1.05	.50	.50	.43	.25	.74[a]
mean	.43	.53	1.18	.72	.38[b]	1.48	1.77	1.67	1.63	1.40	2.05	2.02	1.72	.28[b]
Internal, surface; also pitted (P) where marked:														
Initial	0.5	0.4	0.4	.43	.40	0.1	0.5	0.2	0.5	0.7	0.5	0.4	.41	.41
100/80	.4	.6	.5	.50	.17	.9P	.9	1.2P	1.8P	1.2P	1.1P	1.0	1.16	.51
100/57	.4	.3	.7	.47	.17	.6	1.1P	.9	.9	1.7P	2.1P	.7	1.14	.17
70/80	.9P	.5	.8	.73	.12	.7	1.3P	.9	1.2P	1.3P	1.2P	1.0	1.09	.28
70/57	.4	.3	1.0	.57	.12	.7	1.3P	1.0	.8	1.2	.8	1.0	.97	.23
40/57	.4	.5	.9	.60	.39	.4	1.4P	.5	1.0	1.1	.8	.9	.87	.28
0/amb	.5	.3	.7	.50	.17	.3	1.2P	.5	1.1	1.1	.7	.7	.80	.23
std.dif., cans	.19	.12	.29	.21	----	.19	.32	.53	.28	.19	.29	.17	.30	----
sign.dif., 5%	.32	.21	NS	NS	.35[a]	.32	NS	NS	.48	.32	.51	NS	.17	.49[a]
mean	.50	.42	.77	.56	.13[b]	.60	1.20	.33	1.13	1.27	1.13	.88	1.00	.18[b]

[a] Significant difference for items in rooms.
[b] Significant difference for item means.

TABLE 6

CORROSION OF CARBOHYDRATE SUPPLEMENT CANS STORED 48 MONTHS
(0-9 scale, 0 = none)

Condition °F/% r.h.	5-gallon type									
	CD11	CD12	CD13	Mean	Std.dif. cans	CD11	CD12	CD13	Mean	Std.dif. cans
	External, pitted:					Internal, surface; also pitted (p) where marked:				
Initial	.5	.6	.4	.47	.22	.5	.7	.5	.59	.13
100/80	3.4	.15	3.4	2.77	.78	1.4P	1.1P	1.3P	1.27	.17
100/57	1.3	.6	2.3	1.40	.17	1.2P	1.2P	1.3P	1.23	.29
70/80	1.7	.8	2.2	1.57	.29	.9	.9	1.2P	1.00	.29
70/57	.4	.4	3.0	1.27	1.16	.9	.9	1.2P	1.00	.40
40/57	.7	.2	1.3	7.3	.26	.6	1.0	1.2P	.93	.17
0/amb	.8	.3	1.0	7.0	.26	.6	.9	1.2P	.90	.29
std.dif.,cans	.40	.43	.87	.61	----	.25	.28	.31	.28	----
sign.dif., 5%	.68	.74	1.50	.61	1.01[a]	.43	NS	NS	NS	NS[a]
Mean	1.38	.63	2.20	1.41	.28[b]	.93	1.00	1.23	1.06	.28[b]

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

TABLE 7

DEFECTS IN CAN COATINGS
(0-9 scale, 0 = none)

Condition °F/% r.h.	2½-gallon type CD1	CD3	CD4	Mean	Std.dif. cans	5-gallon type CD2	CD5	CD6	CD7	CD8	CD9	CD10	Mean	Std.dif. cans
Cereal Items Stored 60 Months:														
Initial	0.3	0.4	0.6	.43	.39	0.4	0.6	0.3	0.5	0.4	0.5	0.5	.46	.35
100/80	.4	.5	1.8	.90	.26	2.0	2.6	4.3	1.7	1.8	3.4	2.5	2.61	2.10
100/57	.2	.3	1.9	.80	.20	1.5	1.1	2.0	1.2	1.2	1.9	.9	1.40	.92
70/80	.6	.6	2.0	1.07	.24	2.0	1.7	1.9	1.1	1.0	2.2	1.8	1.67	.46
70/57	.5	.5	1.9	.97	.20	.8	1.6	1.7	1.0	1.1	1.4	.8	1.20	.45
40/57	.2	.5	1.5	.73	.20	.9	1.7	1.5	.4	.7	1.8	1.4	1.20	.26
0/amb	.3	.2	1.2	.57	.26	1.1	.9	1.9	.9	.8	2.1	.6	1.19	.28
std.dif.,cans	.17	.17	.32	.23	----	.43	.37	2.37	.44	.47	.49	.46	.98	----
sign.dif., 5%	NS	NS	NS	.20	NS[a]	.75	.64	NS	.77	.82	.85	.81	.55	1.58[a]
Mean	.37	.43	1.72	.84	.14[b]	1.38	1.60	2.22	1.05	1.10	2.13	1.33	1.55	.59[b]

Carbohydrate Supplement Cans Stored 48 Months:

	5-gallon type CD11	CD12	CD13	Mean	Std.dif. cans
Initial	.4	.5	.4	.44	.26
100/80	2.6	1.5	2.4	2.17	.35
100/57	2.3	1.4	2.3	2.00	.44
70/80	1.8	1.7	1.7	1.73	.29
70/57	1.2	.9	2.5	1.53	.35
40/57	1.2	.5	1.6	1.10	.20
0/amb	1.5	.6	1.5	1.20	.12
std.dif.,cans	.39	.24	.29	.31	----
sign.dif., 5%	.67	.41	.50	.28	.49[a]
Mean	1.77	1.10	2.00	1.62	.20[b]

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

Internal. Differences from previous high values for internal corrosion were merely fluctuation, none greater than 0.6. Average trends for the values of Tables 5 and 6, as changes from previous high ratings, were:

	100°		70°		40°	0°	Period
	30%	57%	80%	57%	57%	amb.	Mean
cereal, 2½-gallon	-.50	-.57	-.30	-.27	-.40	-.43	-.17
cereal, 5-gallon	-.20	+.12	-.26	-.21	-.23	-.26	+.05
supplement, 5-gallon	+.20	+.23	+.07	-.10	.00	.00	+.22

Practically all of the internal corrosion was at spots where the product was in direct contact with the can walls. This was particularly the case with the hard candy supplements, which had no wrapping or can-lining material. Small discolored areas were frequently observed on the surface of the candy, and in some instances on cereal items having torn wrappers which allowed product units to rest against the metal surface of the can.

4. Defects of Can Coatings (Table 7)

Two types of defects in coatings averaged somewhat higher than at previous examinations on 5-gallon cans stored at the 100° and 70°F conditions. They were removal of coating by corrosion or abrasion on the carbohydrate supplement cans, and moderate yellowish discoloration of coatings on the cereal item cans. Neither defect was very serious, merely more pronounced than on former observations. Differences between the values of Table 7 and previous high ratings averaged as follows:

	100°		70°		40°	0°	Period
	80%	57%	80%	57%	57%	amb.	Mean
cereal, 2½-gallon	-.27	-.08	-.13	-.13	-.07	-.35	+.01
cereal, 5-gallon	+.66	+.69	+.47	+.42	+.13	-.02	+.44
supplement, 5-gallon	+1.13	+.67	+.60	+.43	-.18	+.03	+.63

As seen, the condition of coatings on the 2½-gallon cans, and on the 5-gallon cans from the lower temperatures, did not vary greatly during the last storage period.

III. The Rations

A. Cereal Items

1. Condition of Packages (Table 8)

The percentages of broken seals and torn packages were calculated from the numbers of packages per can. These were 15 for CD1, 3 and 4, 24 for CD2, 5, 7 and 8, 28 for CD6, and 126 for wafers CD9 and 10. Only seal breaks or torn places large enough for one unit of product to escape the package were

counted. Thus, many packages with small corner perforations, sufficiently large to allow the product to touch the inside surface of the can (as mentioned above in connection with internal corrosion) but not to allow units to slip out of the package, were not included in the data for package breakage shown in Table 8.

Broken Seals. As seen in Table 8, seal breaks in the cellophane wrap CD6, the waxed paper wraps CD2 and CD7, and the compactly packed wafers CD9 and CD10 (in glassine) averaged lower (mean 11.1% lower) than those in the loosely packed crackers and biscuit CD4, in glassine. General averages in CD4, 6, 9 and 10 were higher than at any previous period (mean increase 1.95%), while CD1, 3, 5 and 8 averaged 4.25% lower than previous highs and CD2 and 7 were practically the same. Thus there was little indication of increase in broken seals, although the fifth year general average was 0.85% above that at 3 years, which was the previous periodic high value. There appeared to be some tendency for the 57% conditions to average higher than 80% conditions at 100° and 70°F, and for increased seal breakage at 0°F, but as seen from the data, differences among individual cans were much too great to allow any definite conclusion concerning a temperature or condition effect.

Torn Packages. The values for torn packages given in Table 8 were about as usual for CD2 (no tearing) and CD10; wafer CD9 was slightly above the previous average of 0.33%. Tearing of glassine wrappers of CD1 and 3 was slightly lower than normal (2.2%), and CD4 was definitely lower (previous average 6.4%). CD6 (cellophane) was about 14% above average, though 7% below the 2-year value. CD5 (glassine) and CD7 (waxed paper) were 3.1% above previous highs and the glassine of CD8 had 25% more tearing than previously observed. In general, torn wrappers appear to be increasing, overall averages for the 9 items excluding CD2 being 1.76% for the first 18 months, 5.09% for 2-4 years, and 9.32% for 5 years. As with broken seals, can differences were too great for definite statements of actual condition effects, although the room means shown in Table 8 differed statistically.

Total Packages Broken. Total broken packages were essentially the sums of seal breaks and torn wrappers, although averaging about 0.6% less because a few packages with broken seals also had holes. Only CD7, CD8 and the wafers were above previous high percentages, but the general average excluding CD2 was 15.7% above the 12-month value, 11.9% above the 18 months and 48 months mean, and 5.3% above the mean highs at 24 and 36 months. Thus broken packages appear to be increasing gradually with storage, and the condition values shown in Table 8 also suggest that slight leaking in the 80% rooms and increased brittleness at 0°F may have influenced the spread of 9.7% to 25.5% among these means.

TABLE 8

PACKAGE DEFECTS IN CEREAL ITEMS STORED 60 MONTHS
(as percent of packages)

Condition °F/% r.h.	Crackers CD1[a]	Crackers CD3[a]	Crackers CD5	Crackers CD8	Biscuits CD2[b]	Biscuits CD4[a]	Biscuits CD6[c]	Biscuits CD7[b]	Wafers CD9	Wafers CD10	Mean	Std.dif. cans
Broken Seals:												
100/80	.0	10.0	2.1	4.2	.0	26.7	1.8	.0	4.8	1.6	5.11	8.30
100/57	6.7	10.0	20.8	6.3	.0	23.3	1.8	4.2	2.8	1.2	7.71	8.86
70/80	10.0	13.3	6.3	6.3	.0	16.7	.0	2.1	2.4	3.2	6.03	13.05
70/57	3.3	3.3	2.1	50.0	.0	26.7	.0	8.3	1.6	4.0	9.94	16.19
40/57	6.7	10.0	6.3	12.5	.0	23.3	.0	12.5	2.0	2.0	7.53	4.97
0/amb	16.7	6.7	6.3	18.8	.0	43.3	1.8	2.1	2.0	3.6	10.12	10.93
std.dif.,cans	13.05	15.40	9.17	22.25	-----	13.34	2.55	5.40	2.15	1.27	10.98	-----
sign.dif., 5%	NS	NS	NS	NS	-----	NS	NS	NS	NS	NS	NS	17.56[d]
Mean	7.23	8.90	7.30	16.32	.00	26.68	.90	4.86	2.60	2.60	7.74	6.41[e]
Torn Packages:												
100/80	.0	.0	4.2	8.3	.0	.0	23.2	8.3	3.2	.4	4.77	5.69
100/57	.0	.0	4.2	58.3	.0	3.3	3.6	16.7	1.2	.0	8.74	9.03
70/80	3.3	.0	8.3	10.4	.0	.0	5.4	14.6	.0	.0	4.21	11.12
70/57	6.7	.0	.0	33.3	.0	.0	37.5	16.7	1.6	.8	9.66	14.96
40/57	.0	6.7	2.1	27.1	.0	.0	12.5	16.7	.4	.4	6.59	10.71
0/amb	.0	.0	16.7	45.8	.0	.0	85.7	14.6	.8	.0	16.37	14.00
std.dif.,cans	6.08	.00	11.90	22.16	-----	2.74	15.14	19.40	1.04	.80	11.34	-----
sign.dif., 5%	NS	.01	NS	NS	-----	NS	26.20	NS	1.79	NS	5.46	18.12[d]
Mean	1.67	1.12	5.91	30.58	.00	.56	27.99	14.60	1.20	.27	8.39	6.55[e]

(Continued)

Table 8 (Continued)

Condition °F/% r.h.	Crackers CD1[a]	CD3[a]	CD5	CD8	Biscuit CD2[b]	CD4[a]	CD6[c]	CD7[b]	Wafers CD9	CD10	Mean	Std.dif. cans
Total Packages Broken:												
100/80	.0	10.0	6.3	12.5	.0	26.7	25.0	8.3	6.4	2.0	9.72	9.25
100/57	6.7	10.0	22.9	64.6	.0	26.7	5.4	20.8	4.0	1.2	16.23	10.56
70/80	10.0	13.3	14.6	14.6	.0	16.7	5.4	16.7	2.4	3.2	9.68	18.25
70/57	10.0	3.3	2.1	70.8	.0	26.7	37.5	22.9	3.2	4.8	18.14	16.60
40/57	6.7	16.7	8.3	39.6	.0	23.3	12.5	29.2	2.4	2.0	13.86	13.65
0/amb	16.7	6.7	18.8	60.4	.0	43.3	85.7	16.7	2.8	3.6	25.46	17.22
std.dif.,cans	15.15	15.41	15.01	24.77	-----	13.05	14.86	21.05	2.10	1.14	14.65	-----
sign.dif., 5%	NS	NS	NS	42.86	-----	NS	25.72	NS	NS	2.01	6.56	23.42[d]
Mean	8.34	10.00	11.81	43.76	.00	27.24	28.58	19.09	3.53	2.80	15.51	9.02[e]

[a] 2½-gallon cans; all others 5-gallon.
[b] Waxed paper.
[c] Cellophane; all others waxed glassine.
[d] Significant difference for items in rooms.
[e] Significant difference for item means.

2. Condition of Products (Table 9)

Defects of products were calculated as percentages of score-lines broken in the multi-unit layers and percentages of broken units. Can totals determined for these calculations were as follows:

CD	Score Lines	Units	CD	Score Lines	Units
1	227	454	5	1286	1286
2	1172	1172	6	1713	1713
3	906	906	7	1363	1363
4	223	446	8	584	1168

Wafers CD9 and CD10 both had 756 units per can, packed as individual units (six units per package, no score lines).

Score Lines Broken. Breakage of score lines in items CD1-CD8 exhibited the usual can and condition fluctuations, but no trend associated with storage beyond the second year. Crackers averaged 1.3% below previous high values, 0.8% above the 12-48 months mean. Biscuits averaged 1.9% below previous highs and exactly the same as the 12-48 months mean. Product averages, 16.5% for crackers and 5.9% for biscuits, were 1.3% above the 12-18 months mean, 0.2% below the mean for 24-48 months. There were no consistent differences associated with storage conditions for crackers or biscuits.

Crumbled edges of wafers, as given in Table 9, were approximately "average" in CD9 except at 100°/57%, which was 11% lower than usual. The wafers of CD10 at 40°/57% were "average", but the other 5 conditions were 21% below previous means, CD10 having averaged 50% crumbled edges through the first 4 years. As with crackers and biscuits, there were no significant trends for differences associated with storage conditions.

Moderate Unit Breakage. Breakage of individual units varied somewhat more among items, but less between cans, than did score-line breakage; CD3 was 3.3% below the previous mean, CD5 was 6.3% above. As product groups, crackers averaged 2.9% below previous high values, 0.4% above previous mean value; biscuits were 2.8% below previous highs and 0.6% below previous mean; wafers were 0.34% below former highs, 0.15% below the 1-4 years mean. There were no indications of consistent differences associated with storage conditions, and the 10-item mean, 8.43%, was almost identical with the 1-4 years general mean, 8.47%.

Crushed Units. As seen in Table 9, differences between duplicate cans were generally larger than either item or storage condition differences in percentage of crushed units. Wafer CD9 has had no crushing; the mean of 0.30% for the crackers biscuits and wafer CD10 was 0.26% lower than the 1-4 years mean. Thus crushing of cereal item units, observed only in dented cans, has been and remains practically negligible.

TABLE 9

PRODUCT BREAKAGE IN CEREAL ITEMS STORED 60 MONTHS
(as percent of total units)

Condition °F/% r.h.	Crackers				Biscuits				Wafers[b]		Mean	Std.dif. cans
	CD1[a]	CD3[a]	CD5	CD8	CD2	CD4[a]	CD6	CD7	CD9	CD10		
Score Lines Broken in Layers:												
100/80	15.5	12.3	32.8	5.4	4.7	2.7	2.7	25.3	35.2	25.7	12.66	5.89
100/57	37.2	9.7	11.7	11.2	3.7	2.5	.3	6.0	23.2	24.9	10.28	16.06
70/80	27.4	14.0	20.5	12.8	5.5	5.4	.9	11.0	30.9	34.9	12.21	14.08
70/57	5.1	12.1	14.7	10.9	3.6	6.5	.9	16.7	35.6	31.7	8.79	4.84
40/57	27.9	16.0	11.7	11.3	4.5	6.1	1.3	5.7	35.2	47.4	10.55	5.84
0/amb	33.8	16.7	17.7	7.6	3.9	4.7	1.4	14.7	27.6	31.4	12.58	3.00
std.dif.,cans	24.89	4.12	4.19	2.06	3.56	3.14	1.18	7.81	7.56	3.82	9.64	-----
sign.dif., 5%	NS	NS	7.25	3.71	NS	NS	NS	NS	NS	6.81	NS	NS[c]
Mean	24.48	13.47	18.18	9.88	4.32	4.63	1.23	13.23	31.30	32.68	11.18[b]	5.61[d]
Moderate Unit Breakage:												
100/80	8.6	6.0	22.2	8.5	1.4	10.5	4.1	6.9	.2	.2	6.85	4.24
100/57	20.5	10.9	34.6	16.2	.7	14.7	1.6	4.2	.0	.0	10.34	6.28
70/80	10.0	6.2	39.7	14.1	1.6	12.5	1.0	5.8	.0	.0	9.10	2.26
70/57	7.5	6.8	18.2	18.3	.7	14.7	2.2	6.9	.3	.4	7.61	1.51
40/57	9.7	9.7	21.8	10.5	1.5	14.5	2.0	6.4	.2	.0	7.63	5.02
0/amb	20.2	14.7	15.4	16.2	1.0	13.9	3.3	6.1	.0	.0	9.08	4.48
std.dif.,cans	8.03	3.52	9.26	2.31	.31	3.43	1.48	1.08	.37	.37	4.29	-----
sign.dif., 5%	NS	NS	NS	4.21	.53	NS	NS	NS	NS	NS	1.92	6.85[c]
Mean	12.78	9.02	25.33	13.98	1.15	13.47	2.36	6.02	.13	.10	8.43	2.48[d]

(Continued)

Table 9 (continued)

Condition °F/% r.h.	Crackers CD1[a]	CD3[a]	CD5	CD8	Biscuits CD2	CD4[a]	CD6	CD7	Wafers[b] CD9	CD10	Mean	Std.dif. cans
Units Crushed:												
100/80	.0	.0	1.0	.0	.0	.0	.0	.2	.0	.0	.12	.16
100/57	1.9	.0	.7	1.2	.0	.0	.0	.1	.0	.0	.40	1.28
70/80	.0	.0	1.1	1.5	.0	.0	.0	.3	.0	.0	.29	.41
70/57	.0	.0	.3	.9	.0	.0	.0	.1	.0	.0	.14	.14
40/57	.0	.0	.9	.1	.0	.0	.0	.0	.0	.0	.10	.05
0/amb	2.9	.0	.8	1.8	.0	.0	.0	.3	.0	.0	.57	1.89
std.dif.,cans	2.80	-----	.71	.78	-----	-----	-----	.27	-----	-----	.95	-----
sign.dif., 5%	NS	-----	NS	NS	-----	-----	-----	NS	-----	-----	NS	NS[c]
Mean	.79	.00	.81	.93	.00	.00	.00	.14	.00	.00	.27	.55[d]
Total Product Breakage:												
100/80	16.3	18.2	53.1	11.2	6.1	11.8	6.7	32.1	35.4	25.9	19.46	8.23
100/57	40.9	20.6	46.7	23.0	4.4	16.0	1.9	10.3	23.2	24.9	20.49	7.19
70/80	23.7	20.2	57.4	22.1	7.1	15.2	2.0	16.9	30.9	34.9	20.57	9.46
70/57	10.0	18.9	32.5	24.7	4.3	18.0	3.0	23.6	35.9	32.1	16.89	4.97
40/57	23.6	25.7	34.4	16.2	6.0	17.5	3.3	12.0	35.4	47.4	17.33	6.19
0/amb	39.4	31.4	33.1	21.8	4.9	16.3	4.7	21.0	27.6	31.4	21.58	8.04
std.dif.,cans	13.28	6.14	11.17	3.54	3.64	3.45	2.51	8.13	7.57	3.62	7.49	-----
sign.dif., 5%	NS	NS	NS	6.12	NS	NS	NS	NS	NS	6.26	NS	12.03[c]
Mean	25.68	22.49	42.87	19.85	5.47	15.78	3.59	19.35	31.43	32.78	19.39[b]	4.36[d]

[a] $2\frac{1}{2}$-gallon cans; others are 5-gallon.
[b] Values for wafers, which are separate units, are for crumbled edges; not included in mean values for score line breakage and total product breakage.
[c] Significant difference for items in rooms.
[d] Significant difference for item means.

Total Product Breakage. Total breakage, calculated from total units per can as given above, was the sum of score line and unit breakage, with two exceptions: (1) score line breakage in 2-unit layers was counted at half value for total, as there were twice as many units as score lines, and (2) combined breakage per layer was limited to two breaks for 2-unit layers and four breaks for 4-unit layers, even though three and five-eight breaks may have been counted for separate calculations of score-line and unit breakages. As shown in Table 9, crumbled edges instead of score-line breaks are included for wafers CD9 and 10, but the general condition means and total mean value (19.39%) included only crackers and biscuits.

Total breakage of crackers averaged 3.5% below previous high percentages and 0.3% below previous general mean; biscuits averaged 3.9% below former highs and 0.7% below former mean. For wafers, most of the breakage being crumbled edges, the average of CD9 was 11.5% below the previous high and 1.6% below mean of 1-4 years, but CD10 was unusually low, 42% below previous high and 18% below previous general mean.

Thus for cereal items as a whole, product breakage was apparently associated predominantly with item and can variances, was apparently not increasing with storage, and was apparently unrelated to storage conditions.

3. Appearance and Color (Table 10)

Sensory scores were assigned by five experienced judges who have a performance record of reacting in similar manner to sample differences (mean can variance ± 0.29), although tending to use somewhat different rating levels (mean judge variance ± 1.07) on the 10-1 scale indicated in Table 10. Samples were presented six per session (one from each storage room), two sessions per item, so duplicate cans were scored on different sessions; all samples were identified, and comparisons among storage conditions were invited in the comments.

There was some general reduction of appearance-color scores after the fifth year of storage, the decrease apparently resulting from a slight increase in glazed appearance at lower temperatures and a slight darkening at 100° and 70°F. These reasons are those noted in comments; numerically, the mean decrease from the fourth year was 0.38, and no condition decrease varied from this mean by more than 0.08. As the mean of Table 10 is 0.56 below the mean of 12-36 months, there appears to have been a gradual decrease in appearance-color scores during the last two years, and the 5-year mean is 0.74 below initial. Association of scores with storage conditions is still fairly indefinite, the 100° and 70°/80% conditions averaging 6.49, the 70°/57% and lower temperatures averaging 6.72. Cracker CD5 and wafer CD10, both dark or "toasted" in appearance, were the low-scoring items at 5 years, but cracker CD3 and all biscuits except CD4 also averaged lower (0.22) than at any previous examination.

TABLE 10

APPEARANCE-COLOR AND TEXTURE SCORES OF CEREAL ITEMS STORED 60 MONTHS
(scale from 10 = excellent to 1 = poor)

Condition °F/% r.h.	Crackers				Biscuits				Wafers		Mean	Std.dif. cans
	CD1	CD3	CD5	CD8	CD2	CD4	CD6	CD7	CD9	CD10		
Appearance-Color:												
Initial	6.5	7.0	7.5	7.0	8.2	7.85	6.8	8.3	7.7	6.5	7.34	-----
100/80	6.7	6.65	5.9	6.35	6.75	6.9	6.65	6.4	6.5	5.7	6.45	.40
100/57	6.8	6.95	6.1	6.6	6.95	6.45	6.6	6.5	6.55	5.7	6.52	.41
70/80	6.65	6.25	6.0	6.7	7.2	6.45	6.55	6.7	6.55	5.9	6.50	.46
70/57	6.8	7.15	6.45	7.1	7.15	6.6	6.6	6.85	6.9	5.9	6.75	.47
40/57	6.95	6.55	6.40	6.7	6.9	6.95	6.7	6.8	6.95	5.6	6.65	.33
0/amb	7.2	6.9	6.15	6.8	6.85	6.95	6.9	6.8	7.0	5.95	6.75	.39
std.dif.,cans	.69	.65	.28	.15	.33	.26	.59	.21	.26	.27	.41	-----
sign.dif., 5%	NS	NS	.49	.26	NS	.45	NS	.37	.45	NS	.19	NS[a]
Mean	6.85	6.74	6.17	6.71	6.97	6.72	6.67	6.68	6.74	5.79	6.60	.24[b]
Texture:												
Initial	6.5	7.3	6.8	7.4	7.8	8.2	6.4	8.2	6.2	5.8	7.04	----
100/80	5.6	6.2	5.8	5.7	6.3	6.8	6.0	6.8	5.6	5.2	6.00	.49
100/57	5.9	5.8	6.1	6.0	6.5	6.8	6.1	7.1	5.7	5.0	6.10	.52
70/80	6.4	6.1	6.0	6.4	7.1	7.3	5.9	7.5	5.7	5.0	6.34	.39
70/57	6.5	6.5	6.4	6.5	7.0	7.2	6.1	7.6	5.8	5.0	6.46	.38
40/57	6.6	6.4	6.4	6.4	7.2	7.4	6.1	7.6	6.0	5.6	6.57	.27
0/amb	6.4	7.1	6.4	7.0	7.0	7.4	6.1	7.7	6.4	5.5	6.70	.44
std.dif.,cans	.65	.32	.19	.39	.28	.30	.19	.36	.83	.25	.42	----
sign.dif., 5%	NS	.56	.32	.67	.48	NS	NS	NS	NS	.43	.19	NS[a]
Mean	6.23	6.35	6.18	6.33	6.85	7.15	6.05	7.38	5.87	5.22	6.36	.25[b]

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

4. Hunter Color Values (Table 11)

Color values were determined on duplicate samples from each can, chopped and sieved to 14-mesh, using a Hunter type color and color difference meter set with NBS reference Maize (L= 73.8, a = 1.4, b = 31.4).

Hunter L. The L value, a measure of "lightness" of color, tends to increase with fading of color or glazing of sample surface, or decrease with darkining or dulling of the surface. While the L values of Table 11 show that all items continued to be somewhat more glazed and slightly lighter at the higher temperatures, comparison with previous values indicated some tendency to darken during the fourth year and definite through moderate darkening during the fifth year.

From high values at 24-36 months, mean decreases in L were 1.0 at 100°F and the two lower temperatures for crackers CD3 and CD5, 1.7 at 100° and 70° and 1.3 at lower temperatures for the biscuits, 2.9 at 100° and 1.4 at the lower temperatures for crackers CD1 and CD8, and 3.8 at 100°, 2.5 at 70° and 40°, 0.5 at 0° for the wafers. All products retained higher values than initial, but the greater decreases at the higher temperatures were readily detected and scored down as "dulling" or slight darkening by the sensory score panel.

Hunter a. The "a" values indicate relative amounts of red color when positive, green when negative; the "pale" items CD3 and CD4 were more green than red, but values were so small that the predominant hue was yellow. The red component of other items (Table 11) resulted in appearance ranging from light tan for CD2 to deep brown for CD5 and CD10.

The characteristic change in "a" values through the third, and in some items the fourth year was a decrease as the color tended to fade, particularly at higher temperatures. At the fifth year the tendency to begin to darken was reflected in a general increase from low values recorded at the periods of maximum fading. This increase was very slight to negligible in cracker CD1, biscuit CD6 and wafer CD10, all dark-color products, increases averaged 0.2 at 100°F, -0.2 at 70°, 0.0 at 40°,and -0.1 at 0°, or actually no significant change in these items. Crackers CD3, light-colored, and CD5, dark, changed little, averaging 0.7 increase at 100°, and 70°, 0.5 at 40°, no change at 0°. The other five items, all moderately light in color except wafer CD9, increased by averages of 1.1 to 1.2 at all temperatures.

As seen in Table 11, "a" values still averaged lighter than initial in about 65% of the samples from 100°, 55% of those from 70°, 50% of those from 40°, and 40% of those from 0°, but the mean increase of 0.8 from previous low values included more than 80% of all samples. Thus the slight tendency to darken, observable by eye in many instances as "dulling" seems definitely established at the fifth year of storage.

TABLE 11
HUNTER COLOR VALUES OF CEREAL ITEMS STORED 60 MONTHS

Condition °F/% r.h.	Crackers				Biscuits				Wafers		Mean	Std.dif. cans
	CD1	CD3	CD5	CD8	CD2	CD4	CD6	CD7	CD9	CD10		
L Values:												
Initial	61.8	69.0	58.3	68.8	68.7	73.4	59.7	69.6	60.8	55.2	64.53	1.31
100/80	64.8	73.1	62.8	72.7	72.4	76.6	65.1	73.8	61.8	56.0	67.90	.81
100/57	64.1	73.0	63.7	71.4	71.5	76.7	64.2	73.4	61.6	55.6	67.52	1.38
70/80	65.3	73.3	63.8	72.3	72.6	75.1	63.3	72.7	63.4	57.8	67.94	1.90
70/57	63.4	72.8	62.2	70.7	70.7	75.0	63.8	71.5	62.5	58.3	67.07	1.32
40/57	62.3	71.8	60.8	72.6	69.7	75.5	62.2	71.7	61.1	56.8	66.43	.76
0/amb	62.6	70.4	59.4	68.8	69.4	74.4	61.5	71.6	61.5	58.2	65.77	1.08
std.dif.,cans	2.07	.82	1.57	.52	.40	1.11	.86	1.20	1.12	1.89	1.27	-----
sign.dif., 5%	NS	1.42	2.81	.90	.69	NS	1.49	NS	NS	NS	.57	2.02[a]
Mean	63.75	72.39	62.08	71.43	71.01	75.53	63.35	72.42	61.96	57.12	67.10	.73[b]
"a" Values:												
Initial	5.1	1.2	6.7	2.6	2.0	0.6	5.2	2.5	3.7	5.0	3.46	.63
100/80	4.0	1.1	5.1	2.2	1.5	1.4	3.7	1.8	4.0	5.2	2.98	.49
100/57	4.3	1.2	4.7	2.8	1.9	1.0	4.4	1.9	4.3	4.6	3.10	.76
70/80	3.7	.8	5.6	2.3	1.5	1.8	4.3	2.5	3.9	4.0	3.03	.59
70/57	4.2	1.4	5.5	2.8	2.0	1.9	4.3	2.8	4.1	4.0	3.29	.63
40/57	4.4	1.5	5.9	2.3	2.5	1.5	4.8	2.7	4.5	4.5	3.45	.63
0/amb	4.6	1.8	6.3	3.2	3.1	2.2	4.9	3.0	4.1	4.1	3.73	.46
std.dif.,cans	.47	.39	.66	.48	.42	.38	.70	.87	.47	.93	.61	-----
sign.dif., 5%	NS	NS	NS	NS	.72	.68	NS	NS	NS	NS	.28	NS[a]
Mean	4.20	1.29	5.50	2.60	2.06	1.63	4.38	2.43	4.16	4.38	3.26	.36[b]

(Continued)

Table 11 (continued)

Condition °F/% r.h.	Crackers CD1	CD3	CD5	CD8	Biscuits CD2	CD4	CD6	CD7	Wafers CD9	CD10	Mean	Std.dif. cans
"b" Values:												
Initial	25.0	21.6	24.8	21.9	19.9	19.6	24.0	22.0	21.3	19.5	21.96	.32
100/80	24.4	19.6	25.0	21.3	18.7	17.9	24.2	20.1	20.8	19.1	21.12	.41
100/57	24.1	20.2	25.8	21.2	18.9	18.0	24.3	20.2	21.0	19.0	21.26	.51
70/80	23.8	18.2	25.0	19.9	17.8	17.7	24.0	20.3	20.2	18.5	20.52	.59
70/57	24.0	19.1	25.2	20.0	18.5	17.9	23.8	20.6	20.0	18.4	20.75	.33
40/57	24.4	19.8	25.3	20.6	18.9	17.5	24.0	20.6	20.7	17.7	20.93	.22
0/amb	24.5	20.3	25.4	20.4	19.1	17.7	24.1	20.3	20.3	18.1	20.99	.24
std.dif.,cans	.60	.19	.48	.38	.41	.39	.30	.45	.30	.39	.40	-----
sign.dif., 5%	NS	.33	NS	.66	.70	NS	NS	NS	.51	.69	.18	.64[a]
Mean	24.21	19.53	25.27	20.57	18.62	17.75	24.05	20.33	20.48	18.45	20.93	.25[b]
a/o Ratios:												
Initial	.203	.054	.269	.120	.097	.030	.219	.115	.173	.256	.158	.027
100/80	.162	.059	.203	.102	.080	.077	.152	.088	.192	.271	.141	.024
100/57	.179	.060	.182	.132	.099	.053	.179	.094	,206	.241	.146	.036
70/80	.157	.041	.223	.114	.083	.103	.177	.121	.195	.216	.147	.026
70/57	.177	.071	.219	.141	.107	.106	.179	.135	.205	.216	.159	.030
40/57	.181	.073	.231	.112	.130	.087	.202	.131	.217	.253	.165	.032
0/amb	.186	.090	.248	.158	.161	.125	.204	.148	.202	.225	.177	.024
std.dif.,cans	.023	.021	.016	.022	.021	.027	.030	.042	.024	.050	.029	------
sign.dif., 5%	NS	NS	.029	NS	.036	NS	NS	NS	NS	NS	.014	NS[a]
Mean	.174	.066	.218	.126	.111	.092	.182	.120	.203	.237	.156	.017[b]

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

Hunter b. The "b" value, denoting yellow when positive, blue when negative, normally increases with fading of the "red" or "a" color component, but decreases with browning or "dulling" of color in baked products. The characteristic change through four years was increase; although highest period averages ranged 12-48 months, average 30 months, changes from these highs were relatively slight through the fourth year. This slight shift toward darkening (decrease in "b") was more pronounced after the fifth year, all items decreasing from previous low values of "b" except cracker CD5 and biscuit CD6, both dark-baked items. These two were below the highs recorded at periods of maximum fading, but still above previous lows.

Evaluated as decreases from previous lows for "b", darkening in cracker CD1 and wafer CD10, both dark-baked, averaged 0.1 at 100°, 0.6 at 70°, 0.2 at lower temperatures. Cd9, the lighter of the wafers, and cracker CD8 and biscuit CD7, light-baked items, averaged 0.7 at 100° and 40°, 1.2 at 70°, 1.0 at 0°. Cracker CD3 and biscuits CD2 and CD4 (the latter being the lightest-color item) averaged 1.8 at 70°, 1.3 at other temperatures. Thus tendency to darken still is relatively negligible in dark-baked items, but light-baked item darkening as decreases in "b" averaged 1.0 at 100° and 40°, 1.2 at 0°, and 1.5 at 70°.

Hunter a/b. In conjunction with decreases in L or "lightness" value, increases in a/b ratio provide a good index of darkening in the shelter rations, as darkening involves increase in "a" but decrease in "b". Average increase at five years above previous low a/b ratios averaged only .014 for the four dark-baked items, cracker CD1 and CD5, biscuit CD6 and wafer CD10. These apparently had little tendency to darken, still averaging .034 below initial and .053 below the highest values from storage.

The moderately light to light items, wafer CD9, crackers CD3 and CD8, biscuits CD2 and CD7, averaged .069 increase from lowest a/b ratios, being about the same as initial and previous high storage averages. The increases averaged .076 from 100°F, .066 from other temperatures. Thus, although decreases in "b" values averaged somewhat greater at 70°, higher average "a" increases at 100° apparently resulted in the slightly greater increase in a/b at this temperature. The lightest item, biscuit CD4, increased .086 at 40°F and .121 at other temperatures, averaging .062 above initial and .041 above previous high ratios from storage.

In summary, although all items except wafer CD10 still average lighter at the higher temperatures as seen in Table 11, the tendency to darken during the fifth or fourth and fifth years became pronounced in the very light items and definite in the moderately light. Fading was usually considered acceptable but darkening and "dulling" resulted in reduction of appearance-color scores.

5. Fracture Strength (Table 12)

Twenty units selected in a systematic manner from each can were used to determine fracture strength. Each unit was supported by four corner blocks of about 1/16 sq. in. area and the dull point of a weighted plunger was

TABLE 12

FRACTURE STRENGTH AND MOISTURE CONTENT OF CEREAL ITEMS STORED 60 MONTHS

Condition °F/% r.h.	Crackers				Biscuits				Wafers		Mean	Std.dif. cans
	CD1	CD3	CD5	CD8	CD2	CD4[a]	CD6	CD7	CD9	CD10		
Fracture Strength, grams:												
Initial	1410	1100	1540	1140	1500	1170	2090	1220	2160	1285	1460	89
100/80	1468	1101	1436	1425	1712	1179	1677	1287	2435	1778	1552	125
100/57	1542	1086	1468	1389	1693	1175	1775	1298	2701	1800	1593	58
70/80	1479	1078	1517	1368	1752	1192	1820	1264	2173	1675	1532	75
70/57	1564	1082	1488	1418	1743	1161	1808	1245	2193	1671	1537	81
40/57	1575	1120	1480	1481	1726	1156	1816	1277	2043	1745	1542	94
0/amb	1652	1126	1557	1401	1781	1159	1810	1305	2207	1722	1572	58
std.dif.,cans	108	73	100	68	33	75	33	47	161	70	85	----
sign.dif., 5%	NS	NS	NS	NS	NS	NS	57	NS	277	NS	41	135[b]
Mean	1547	1099	1494	1414	1734	1170	1784	1279	2292	1732	1554	49[c]
Moisture Content, percent:												
Initial	1.85	2.21	1.42	3.53	1.91	1.69	2.74	1.96	4.01	4.03	2.53	.29
100/80	3.15	2.95	1.71	2.94	2.70	2.03	3.10	2.18	3.71	4.01	2.85	.39
100/57	2.57	3.21	1.95	3.27	2.63	2.21	2.84	2.16	3.99	3.97	2.88	.32
70/80	3.14	3.47[a]	1.54	3.07	3.36	2.20	2.60	2.05	3.86	3.88	2.92	.24
70/57	2.45	2.45	1.81	2.85	2.66	1.84	2.68	1.64	3.92	3.84	2.61	.30
40/57	2.85	2.50	1.77	2.93	2.67	2.00	2.75	2.34	4.11	3.56	2.75	.13
0/amb	3.09	2.30	1.60	2.89	2.67	1.87	2.75	2.55	3.86	3.96	2.75	.27
std.dif.,cans	.69	.39	.21	.36	.37	.19	.27	.24	.06	.04	.31	----
sign.dif. 5%	NS	NS	NS	NS	.20	NS	NS	NS	.11	.07	.14	.50[b]
Mean	2.88	2.81	1.73	2.99	2.78	2.02	2.79	2.15	3.91	3.87	2.79	.18[c]

[a] All cans were leakers. Single leakers are included in fracture strength values but are omitted from moisture values, as they averaged 0.54 ± .16% higher than duplicate non leakers.
[b] Significant difference for items in rooms.
[c] Significant difference for item means.

rested on the center of the unit. The plunger carried fixed weights varying from 400 to 1600 grams, depending on the fracture resistance of the unit, and additional weight was added to the point of fracture by applying increasing pressure on the plunger with a 1000-gram spring-loaded pressure tester.

Again, as at previous examinations, there was no consistent pattern for fracture strength as related to storage. Cracker CD3, the most uniform item, was almost exactly average. Cracker CD8 and wafer CD10 were about 200 grams higher than on previous examinations. All other items have exhibited periodic fluctuations of 100-300 grams; at five years, biscuit CD6 was low, items CD1, 2, 4, 5, 7, 9 were high, but none of the seven were higher or lower than at some earlier period.

In general, fracture corresponded only with degree of baking. Light items CD3 and CD4 were tender, moderately brown items CD7 and CD8 were fairly tender. Brown items CD1 and CD5 were brittle, with mid-range fracture, while brown CD6 was somewhat tougher. Biscuit CD2 was tougher than would be expected, as it is a moderately-baked item. Wafer CD9, medium-brown, was quite compact, but wafer CD10 was "toasted" and somewhat crumbly.

6. Moisture Content (Table 12)

Moisture content was determined on duplicate 14-mesh samples from each can as loss of weight after heating 5-gram aliquants 24 hours at 70°C under a 29-inch vacuum.

As usual, there was no consistent relationship of moisutre to anything except leakers, enough of which were located in high humidity rooms to give the average increase of 0.54% in leakers over non-leakers from the same sample (see footnote, Table 12). Items CD1, 2, 3, 6, and 9 averaged somewhat higher moisture than usual, but not higher than at some previous period; CD10 was higher than at any other period, but not higher than initial. CD7 and CD8 were about average. CD4, all leakers, and CD5, no leakers, were lower in moisture than averages of previous examinations, but not lower than at some previous examination. Thus moisture was apparently unrelated to storage time or conditions.

7. Rancidity Values (Table 13)

Peroxides. Peroxide values were determined by extracting fat from the ration samples with chloroform, mixing aliquants of the extract with 1.5 volumes of glacial acetic acid, reacting with potassium iodide, and titrating liberated iodine with potassium thiosulfate. As peroxides are unstable early-stage intermediate products in the complex patterns of fat oxidation, these patterns can be evaluated only in relation to changes in levels of peroxide values and other characteristics of the samples involved.

General patterns in the shelter ration items were similar in some aspects, different in others. All samples increased in peroxide values during the

first year in storage, apparently as a result of initial absorption of can-space oxygen, probable deposits of surface films of fat resulting from baking and the variable effects of handling and adjustments to storage temperatures. Peroxides reached highest levels at 100°F in crackers and biscuits, crackers averaging higher, but at 70°F in wafers.

The wafers had relatively more absorptive structures, greater volumes of products per unit can volume, and more rapid absorption of oxygen, all apparently contributing to more rapid establishment of secondary oxidation reactions which utilized peroxides and which also resulted in off aroma and flavor. Thus peroxides never accumulated to as high levels in wafers at 100° as in the less reactive conditions at 70°, and peroxide values of wafers in general remained lower than in the less absorptive crackers and biscuits.

Following the first-year upswings, peroxides decreased sharply in all products during the second to third years, when off flavors also began to appear in crackers and biscuits. This period apparently was one of relative stability, during which initially-accelerated reactions had slowed down and secondary oxidation mechanisms were utilizing peroxides as fast as they were formed. By the fourth year, a second, moderate upswing in peroxidation was taking place at 100°F and to some extent at 70°, and further shelf life of crackers and biscuits was questionable, although wafers were apparently changing far more slowly.

The peroxide values of Table 13 show the continuation of the second period of active oxidation, levels being generally as high at 70°F as at 100°, with some increase at 40°. It will be noted that, again, wafers remained practically unchanged. Differences between five-year values and previous highs in peroxides were as follows:

	crackers		biscuits		wafers
	1, 3, 8	5	2, 4, 7	6	9, 10
100°F	-18.0	9.1	8.7	-2.2	-2.0
70°F	5.7	12.0	11.0	16.1	-6.6
40°F	4.5	.8	2.8	.9	1.2
0°F	.7	1.2	.8	.4	-1.0

Values increased in CD1, 3, 8 and 6 at 100°F also, but levels reached were lower than those at 12 months. Wafers did not increase in general although all except CD9 at 100° were higher than at 48 months. While variations in methodology could have accounted for some of the increases, the 0°F mean was only 0.86 above the 48-month mean, whereas the mean increases at higher temperatures were 2.44 at 40°, 8.33 at 70°, and 7.34 at 100°, indicating decreased stability of the fat in the rations.

Free Fatty Acids. These were determined by combining equal volumes of neutral ethanol with the chloroform extracts of fats and titrating with ethanolic alkali. As products of fat hydrolysis, free fatty acids are

TABLE 13

RANCIDITY VALUES OF FATS FROM CEREAL ITEMS STORED FOR 60 MONTHS

Condition °F/% r.h.	Crackers				Biscuits				Wafers		Mean	Std.dif. cans
	CD1	CD3	CD5	CD8	CD2	CD4[a]	CD6	CD7	CD9	CD10		
Peroxide Values, milliequivalents per kilogram:												
Initial	1.0	.8	.5	.8	1.0	.3	.9	.8	2.0	1.4	.97	.41
100/80	11.0[b]	9.0	34.8	13.5[b]	7.1[a]	9.9	8.1	23.9	1.5	2.3	12.11	5.89
100/57	12.2[b]	5.8	17.6	10.2	7.1	12.9	5.3	22.1	1.8	1.8	9.67	2.80
70/80	10.8	10.0[a]	17.6	10.0	4.1	15.8	25.7	20.0	8.3	3.0	12.53	8.08
70/57	8.4	8.3	13.0	14.8	7.4	19.5	14.3[a]	19.2	2.7	2.8	11.04	3.87
40/57	2.7	9.9	4.1	3.6	5.2	7.3	4.0[b]	3.7	8.6	5.0	5.40	2.03
0/amb	1.8	3.2[b]	2.5	2.9	3.0	3.7	2.7[a]	2.8	3.4	2.9	2.88	.88
std.dif.,cans	3.37	2.72	9.87	1.98	2.98	4.10	6.37	3.25	4.05	1.20	4.64	-------
sign.dif., 5%	5.82	NS	17.11	3.55	NS	7.09	11.51	5.63	NS	NS	2.08	7.92[c]
Mean	7.81	7.69	14.92	9.15	5.65	11.50	10.01	15.27	4.39	2.98	8.52	2.68[d]
Free Fatty Acids, percent as oleic acid:												
Initial	.17	.23	.19	.36	.16	.60	.14	.27	.34	.32	.280	.029
100/80	.32[b]	.73	.37	.67[b]	.65[a]	1.24	.30	.77	.92	.91	.686	.075
100/57	.29[b]	.78	.33	.83	.72	1.24	.25	.82	.95	.96	.716	.074
70/80	.15	.36[a]	.17	.37	.22	.67	.17	.39	.47	.41	.338	.044
70/57	.14	.31	.17	.37	.17	.62	.17[a]	.37	.48	.43	.324	.059
40/57	.12	.22	.13	.32	.16	.60	.13[b]	.29	.45	.37	.278	.022
0/amb	.12	.23[b]	.11	.35	.16	.56	.10[a]	.30	.42	.38	.274	.020
std.dif.,cans	.019	.063	.017	.055	.066	.093	,036	,058	.047	.037	.054	-------
sign.dif., 5%	.032	.108	.041	.095	.114	.161	.063	.101	.081	.065	.025	.083[c]
Mean	.188	.437	.213	.483	.346	.821	.187	.488	.617	.577	.436	.032[d]

[a] All cans were leakers.
[b] Both cans were questionable leakers. Single leakers varied little from duplicate non-leakers, so are included in values listed.
[c] Significant difference for items in rooms.
[d] Significant difference for item means.

generally proportional to temperature and moisture content, and the higher values for wafers as given in Table 13 could be associated with the higher moisture content of this product. Crackers CD3 and 8 and biscuits CD4 and 7 were not high-moisture products, however, so the fats were apparently less stable in these six items than in crackers CD1 and 5 and biscuits CD2 and 6.

Free fatty acids did not exhibit the periodic variations observed with peroxides, although mean values did tend to increase during the fourth and fifth years of storage. As compared to previous high values, however, CD2, 4, 6, and 10 averaged .24% higher at 100°F, about the same below 100°, while other items averaged 0.10% lower at 100° and 0.04% lower at other conditions. Thus free fatty acids were essentially associated with temperatures and with item differences, the mean value for 40° and 0°F storage for five years being about the same as initial.

3. Sensory Scores for Texture, Aroma and Flavor (Tables 10 and 14)

All sensory scores were obtained as described above for appearance-color.

Texture. The reasons most frequently given for reductions in texture scores were general lack of fresh crispness, with slight increases in hardness or toughness of crackers and biscuits and in crumbling and "grittiness" of wafers at 100°F. Crackers CD1 and 3 averaged somewhat lower than at four years, biscuits CD6 and wafer CD10 lower than at any previous examination, other items were only slightly below average for the five-year period. In general, changes in texture were not considered a major problem.

Aroma. Mean aroma scores for storage at 100°F, Table 14, leave no doubt that the score panel judges considered the 100° items ready for discard. All items except CD1 (mean 4.2) and CD10 (mean 4.9) had been scored below 4.0 at 48 months. Decreases from lowest scores at 3 or 4 years, and mean values for products at 5 years, were as follows:

	crackers		biscuits		wafers	
	decrease	mean	decrease	mean	decrease	mean
100°	1.3	2.0	.9	1.9	1.0	3.2
70°	.8	5.0	.0	5.6	.9	3.9
40°	.6	6.0	-.1	6.4	.6	5.4
0°	.0	6.7	.0	6.8	.3	6.2

Flavor. Every item except wafer CD10 (mean 5.0) had been scored below 4.0 at 48 months. On the scoring scale used by the sensory quality panel, scores below 4.0 denote "fair", i.e., acceptable in emergency but not good (1 on this scale denotes unacceptable under any condition of normal eating). Decreases from lowest scores at 3 or 4 years and mean values at five years were:

TABLE 14

AROMA AND FLAVOR SCORES OF CEREAL ITEMS STORED 60 MONTHS
(scale from 10 = excellent to 1 = poor)

Condition °F/% r.h.	Crackers CD1	CD3	CD5	CD8	Biscuits CD2	CD4	CD6	CD7	Wafers CD9	CD10	Mean	Std.dif. cans
Aroma:												
Initial	7.0	7.2	7.2	6.4	7.7	8.0	6.4	6.4	6.0	6.4	6.87	-----
100/80	1.8	2.4	1.9	1.2	1.5	1.7	2.7	1.3	3.0	3.2	2.07	.32
100/57	2.8	2.7	2.0	1.2	1.9	1.9	2.9	1.6	3.5	3.2	2.37	.39
70/80	5.5	4.5	4.3	4.6	5.1	5.6	5.2	5.6	3.4	3.7	4.75	.57
70/57	6.0	5.5	4.9	4.9	5.9	5.7	5.5	5.9	4.2	4.4	5.29	.36
40/57	6.6	6.1	5.4	6.1	6.4	6.6	6.2	6.5	5.1	5.7	6.07	.50
0/amb	7.3	6.9	6.2	6.5	6.6	7.0	6.7	6.8	6.2	6.2	6.64	.48
std.dif.,cans	.45	.79	.40	.32	.24	.67	.33	.22	.26	.39	.45	-----
sign.dif., 5%	.78	1.41	.68	.56	.41	1.16	.57	.38	.45	.67	.20	.70[a]
Mean	5.00	4.68	4.12	4.08	4.57	4.75	4.87	4.62	4.23	4.40	4.53	.26[b]
Flavor:												
Initial	6.0	7.0	6.3	6.4	8.4	7.5	6.4	7.8	6.2	5.4	6.74	-----
100/80	2.0	2.9	2.4	1.5	1.6	1.7	2.9	1.2	3.6	2.8	2.26	.87
100/57	3.3	3.2	2.6	1.8	2.1	1.9	3.3	1.8	4.3	3.1	2.74	.75
70/80	5.5	5.2	4.6	4.9	4.7	4.6	5.6	5.0	3.9	4.4	4.84	.54
70/57	5.3	5.9	5.2	5.4	5.6	4.7	5.9	5.6	4.8	4.5	5.29	.60
40/57	6.9	6.2	5.9	6.1	6.4	5.8	6.5	6.4	5.7	5.9	6.19	.39
0/amb	7.2	6.9	6.4	6.4	6.9	6.6	6.6	6.9	6.5	6.5	6.69	.47
std.dif.,cans	.57	1.40	.44	.32	.46	.40	.33	.66	.52	.37	.63	-----
sign.dif., 5%	.98	2.42	.77	.56	.79	.68	.57	1.15	.91	.64	.28	.99[a]
Mean	5.03	5.05	4.52	4.35	4.55	4.22	5.13	4.48	4.80	4.53	4.67	.36[b]

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

	crackers		biscuits		wafers	
	decrease	mean	decrease	mean	decrease	mean
100°F	.6	2.5	.7	2.1	1.0	3.4
70°F	.3	5.2	.2	5.2	.2	4.4
40°F	.2	6.3	.1	6.3	.1	5.8
0°F	-.3	6.7	.3	6.7	-.5	6.5

These scores confirm the suggestions made previously that four years should probably be considered the limit for storage of the cereal ration items at 100°F. As seen in Table 15, however, the hedonic ratings for wafers were still above the 4.00 level considered minimal for test samples.

9. Hedonic Ratings for Aroma, Flavor and Palatability (Table 15)

The hedonic rating panel consisted of 25 judges selected at random as available from a pool of about 100 people. Samples were rated in sets of six per judge per session, each set containing one can from each of the six storage conditions for a single item; thus, duplicate cans were scored on different sessions. The six samples for each session were randomly assigned to the six positions of a systematically arranged 6 x 25 block plan, the arrangement being such that each sample appeared in each of the six presentation positions (1st to 6th) about the same number of times, and each of the 25 blocks (plates) had the six samples in a different sequence. Arranged thus, the six samples were presented together, with scoring order numbered, so that direct comparisons could be made by any judge who so desired, and comments on these comparisons were invited. The numerical scale was the customary 9-point hedonic range from "like extremely" to "dislike extremely".

Aroma. During the fifth year, the aroma of wafers changed relatively little from previous low values. Crackers and biscuits decreased at 100°F, but mean changes at lower temperatures were slight. Changes from previous lows, and mean values for the three products were as follows:

	crackers		biscuits		wafers	
	change	mean	change	mean	change	mean
100°F	-.58	3.34	-.64	3.19	.03	4.36
70°F	-.12	5.17	.18	5.55	-.05	4.70
40°F	-.10	5.55	.49	6.08	.05	5.27
0°F	.29	5.97	.40	6.29	.24	5.63
Initial	----	5.85	-----	6.42	----	5.45

Flavor. With approximately the same pattern as for aroma, changes from previous lows, and mean values at 5 years, were as follows:

TABLE 15

HEDONIC RATINGS FOR CEREAL ITEMS STORED 60 MONTHS

Condition °F/% r.h.	CD1	CD3	CD5	CD8	CD2	CD4	CD6	CD7	CD9	CD10	Mean	Std.dif. cans
Aroma:												
Initial	5.58	5.94	5.58	6.28	6.80	6.10	6.24	6.54	5.30	5.60	6.00	.32
100/80	3.50	4.00	3.25	2.65	2.60	3.13	3.63	3.18	4.38	4.23	3.45	.42
100/57	3.63	4.00	3.05	2.63	2.68	3.30	3.78	3.20	4.43	4.38	3.51	.47
70/80	5.80	5.00	4.83	4.78	5.13	5.45	5.45	5.85	4.70	4.48	5.15	.47
70/57	5.88	5.15	5.20	4.75	5.43	5.45	5.58	6.05	5.00	4.63	5.31	.50
40/57	5.93	5.45	5.28	5.55	6.25	5.83	5.78	6.48	5.28	5.25	5.71	.46
0/amb	6.43	5.88	5.75	5.83	6.20	6.15	6.33	6.50	5.70	5.55	6.03	.26
std.dif.,cans	.36	.28	.38	.48	.66	.50	.37	.25	.64	.25	.44	----
sign.dif., 5%	.63	.49	.65	.83	1.14	.86	.63	.43	NS	.43	.20	.70[a]
Mean	5.19	4.91	4.56	4.36	4.71	4.88	5.09	5.21	4.91	4.75	4.86	.27[b]
Flavor:												
Initial	5.54	6.10	5.88	6.06	7.62	6.46	6.20	6.60	5.52	5.68	6.17	.34
100/80	3.53	4.28	3.23	2.73	2.85	3.05	3.85	3.15	4.55	4.18	3.54	.41
100/57	3.78	4.20	3.03	2.85	3.08	3.18	3.83	3.40	4.55	4.60	3.65	.31
70/80	5.83	5.18	4.55	4.80	5.35	5.45	5.43	5.78	5.03	4.98	5.24	.40
70/57	5.58	5.48	4.93	4.90	5.43	5.35	5.63	6.03	5.18	5.08	5.36	.47
40/57	5.98	5.68	5.13	5.40	5.78	5.63	6.10	6.45	5.25	5.60	5.70	.44
0/amb	6.23	5.93	5.70	5.63	6.15	6.08	6.10	6.53	5.83	6.10	6.03	.42
std.dif.,cans	.29	.26	.59	.37	.55	.34	.36	.37	.59	.22	.41	----
sign.dif., 5%	.49	.46	1.01	.64	.94	.58	.62	.64	NS	.40	.19	.66[a]
Mean	5.15	5.12	4.43	4.38	4.77	4.79	5.15	5.22	5.06	5.09	4.92	.24[b]

(Continued)

Table 15 (continued)

Condition °F/% r.h.	Crackers CD1	Crackers CD3	Crackers CD5	Crackers CD8	Crackers CD2	Crackers CD4	Crackers CD6	Crackers CD7	Wafers CD9	Wafers CD10	Mean	Std.dif. cans
Palatability:												
Initial	5.70	6.30	6.06	6.38	7.40	6.40	5.92	6.90	5.36	5.64	6.21	.27
100/80	3.38	4.20	3.03	2.55	2.78	2.98	3.50	3.05	4.45	4.23	3.41	.43
100/57	3.75	4.23	2.88	2.63	2.90	3.20	3.58	3.18	4.43	4.45	3.52	.44
70/80	5.88	5.55	4.63	4.93	5.50	5.70	5.40	5.93	5.03	4.90	5.34	.33
70/57	5.85	5.58	5.10	4.83	5.58	5.68	5.60	6.10	5.23	4.85	5.44	.49
40/57	5.98	5.80	5.18	5.40	6.03	5.98	6.15	6.58	5.30	5.40	5.78	.40
0/amb	6.25	6.10	5.55	5.65	6.33	6.35	6.15	6.58	5.75	5.80	6.05	.33
std.dif.,cans	.30	.28	.44	.32	.55	.29	.40	.29	.70	.20	.40	----
sign.dif., 5%	.51	.49	.86	.55	.95	.50	.69	.51	NS	.33	.18	.64[a]
Mean	5.18	5.24	4.39	4.33	4.85	4.98	5.06	5.23	5.03	4.94	4.92	.27[b]

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

	crackers		biscuits		wafers	
	change	mean	change	mean	change	mean
100°F	-.52	3.45	-.75	3.30	-.17	4.47
70°F	-.08	5.16	.14	5.56	.16	5.07
40°F	-.03	5.55	.21	5.99	-.05	5.43
0°F	.29	5.87	.29	6.22	.33	5.97
Initial	----	5.90	----	6.72	----	5.60

Palatability. Reductions in palatability ratings at 100°F were greater than for aroma and flavor, with other changes and means of similar patterns as follows:

	crackers		biscuits		wafers	
	change	mean	change	mean	change	mean
100°F	-1.14	3.33	-1.35	3.15	-.28	4.39
70°F	-.10	5.29	.18	5.69	-.08	5.00
40°F	.03	5.59	.40	6.19	-.17	5.35
0°F	.29	5.89	.44	6.35	.11	5.78
Initial	----	6.11	----	6.66	----	5.50

Thus, assuming a score of 4.00 represents the lower limit of acceptability as a rule in these studies, crackers and biscuits as shown in Table 15 and summarized above were below the specified level of quality for continued storage at 100°F. Wafers, however, were apparently still considered acceptable, though greatly reduced in quality at this temperature.

10. Correlations of Palatability Ratings with Other Measurements (Table 16)

The correlations of Table 16 were among samples, including temperature effects, for items and product groups. It is seen that many of the correlations with color, residual oxygen, peroxide values, and all with free fatty acids, are significant. This was expected, since the temperature and item characteristics influencing these various parameters also influence aroma, flavor, and palatability. It is noted that agreement of palatability ratings with sensory scores for texture, aroma and flavor (by a different taste panel) remained very high, indicating that sample differences were definite enough to be readily detected.

B. The Carbohydrate Supplements

The hard candies of the carbohydrate supplement consisted of two flavors and colors, lemon and cherry in equal parts. The two types were examined separately for all determinations except taste panel scores, for which only comments were separate. Data and discussions are based on cans and items, however, except in instances where there were distinct differences as in color values, and type variations are noted only when they were observed.

TABLE 16

CORRELATIONS OF PALATABILITY RATINGS WITH OTHER MEASUREMENTS FOR CEREAL ITEMS STORED 60 MONTHS
(simple correlation coefficient, r)

Palatability with:	Crackers					Biscuits					Wafers		
	CD1	CD3	CD5	CD8	All	CD2	CD4[a]	CD6	CD7	All	CD9	CD10	All
Hunter L	-.365	-.638[b]	-.641[b]	-.424	-.091	-.646[b]	-.807[c]	-.857[c]	-.752[c]	-.193	+.024	+.470	+.196
a	+.214	+.423	+.863[c]	+.297	-.084	+.632[b]	+.728[b]	+.605[b]	+.731	+.341[b]	-.003	-.363	-.234
b	-.058	-.168	-.108	-.759[c]	-.141	+.007	-.454	-.557	+.415	+.033	-.604[b]	-.801[c]	-.215
a/b	+.207	+.450	+.862[c]	+.409	-.010	+.659[b]	+.744[c]	+.638[b]	+.728[c]	+.457[c]	+.146	-.212	-.037
Fracture Strength	+.415	+.271	+.566	+.117	-.038	+.711[c]	-.169	+.735[c]	-.233	-.002	-.642[b]	-.327	-.194
Moisture Content	-.289	-.443	-.372	-.400	-.003	+.196	-.467	-.437	+.045	-.084	+.222	-.416	-.116
Residual Oxygen	+.215	+.817[c]	+.788[c]	+.879[c]	+.677[c]	+.958[c]	+.571	+.919[c]	+.977[c]	+.728[c]	+.473	+.778	+.599[c]
Peroxide Values	-.667[b]	-.097	-.734[c]	-.576[b]	-.573[c]	-.401	-.111	+.023	-.717[c]	-.230	+.204	+.489	+.257
Free Fatty Acids	-.976[c]	-.976[c]	-.967[c]	-.937[c]	-.649[c]	-.958[c]	-.990[c]	-.940[c]	-.992[c]	-.644[c]	-.719[c]	-.809[c]	-.750[c]
Sensory Scores:													
Appearance-Color	+.326	-.023	+.544	+.647[b]	+.380[c]	+.143	+.180	+.109	+.785[c]	+.211	+.326	+.328	+.208
Texture	+.666[b]	+.667[b]	+.757[c]	+.767[c]	+.646[c]	+.857[c]	+.858[c]	+.139	+.818[c]	+.413[c]	-.099	+.674[b]	+.175
Aroma	+.973[c]	+.923[c]	+.986[c]	+.983[c]	+.948[c]	+.970[c]	+.984[c]	+.973[c]	+.966[c]	+.975[c]	+.667[b]	+.915[c]	+.778[c]
Flavor	+.927[c]	+.809[c]	+.976[c]	+.982[c]	+.913[c]	+.950[c]	+.966[c]	+.969[c]	+.983[c]	+.949[c]	+.541	+.963[c]	±.762[c]

[a]All cans were leakers.
[b]Significant at the 5% level of probability.
[c]Significant at the 1% level of probability.

The candies were packed in bulk in the cans, average 34.7 lbs. per can, with no lining or stuffing material. One banded packet of 20 kraft bags was included in each can, lying on the top of the candy. The bags were made as pouches by folding a 10¼-inch x 3½-inch strip of kraft at 5 inches (leaving a ¼-inch lip at the top) and sealing up the two sides with ¼-inch seams, thus providing 3-inch by 5-inch internal dimensions.

1. Condition of Candy Bags (Table 17)

Measurements of length of top lip and internal size of bags were discontinued after the initial and first two storage examinations. Bags per can, width of side seams, and seam tests were determined on all examinations.

Bags per can. Counts of usable bags per can (some bags had holes, some were sealed only on one side) at 4 years, and cumulative counts for all cans examined through 4 years, were as follows:

	at 4 years	All cans examined through 4 years	
	bags per can	range	mean
CD11	20	21-16, 1 w/none	19.64
CD12	19.42	21-11, 1 w/none	19.23
CD13	20.08	21-19	20.00
All	19.83	21-11, 2 w/none	19.62

Width of side seams. Normal width of side seams is 04 (4/16 inch). Widths of seams on bags examined at 4 years, and on all bags examined through 4 years, were as follows:

	CD11	CD12	CD13	All
at 4 years				
no. of seams	480	464	462	1446
range of widths	04-07	00-06	04-07	00-06
mean width	04.77	04.74[a]	05.77	05.10[a]
through 4 years				
no. of seams	3024	3044	3080	9148
range of widths	01-07	00-12	02-13	00-13
mean width	04.33	04.51[b]	05.12	04.66[b]

[a] 9 missing seams (00) not included.
[b] 38 missing seams (00) not included.

Over the 4 years, seams less than 04 were: 3.5% @ 03, 5.5% @ 02, 0.6% @ 01 for CD11; 2.6% @ 03, 0.6% @ 02, 1.7% @ 01, 1.2% @ 00 for CD12; 0.3% @ 03, 0.7% @ 02 for CD13, or a mean of 5.6% under 04 for all bags examined.

TABLE 17

RESULTS OF SEAM TEST ON KRAFT BAGS STORED 48 MONTHS IN CARBOHYDRATE SUPPLEMENT CANS

Condition °F/% r.h.	CD11 6-24 mo.	CD11 36-48 mo.	CD12 6-24 mo.	CD12 36-48 mo.	CD13 6-24 mo.	CD13 36-48 mo.	Total 6-24 mo.	Total 36-48 mo.	Std.dif.,cans 6-24 mo.	Std.dif.,cans 36-48 mo.	Mean, Inches[a] 6-24 mo.	Mean, Inches[a] 36-48 mo.
Partial Separation, percentage of seams:												
Initial	4.04%, .062"		2.05%, .062"		2.50%, .125"		2.87%, .081"		4.56%			
100/80	2.2	26.0	1.6	3.0	6.3	1.9	3.33	5.86	6.73	13.67	.109	.178
100/57	11.9	1.3	4.7	1.3	3.7	2.5	6.77	1.67	5.77	2.89	.133	.109
70/80	4.0	.0	2.2	.0	5.6	3.1	3.97	1.05	6.09	2.31	.080	.113
70/57	5.3	.6	1.3	.0	4.4	5.6	3.65	2.08	4.85	2.50	.080	.113
40/57	.9	.0	.0	.0	11.6	6.9	4.35	2.29	17.04	5.11	.144	.193
0/amb	4.1	.0	1.3	.6	4.4	5.8	3.29	2.10	3.20	2.53	.065	.131
Std.dif.,cans	4.44	8.86	4.98	3.80	13.25	5.17	8.56	6.32	------	------		
sign.dif., 5%	3.24	9.66	3.64	NS	NS	NS	NS	3.70	6.05[b]	6.41[b]		
Mean,percent	4.75	4.51	1.89	.84	5.98	4.28	4.23	3.21	2.47[c]	2.62[c]		
Mean,inches[a]	.113	.192	.064	.062	.115	.142	.107	.158				
Complete Separation, percentage of seams:												
Initial	.00		.00		4.50		1.52		5.09			
100/80	.0	.19	.0	.0	8.1	7.5	2.71	3.14	5.69	4.68		
100/57	.0	.0	.0	.0	4.0	6.3	1.35	2.08	4.86	8.42		
70/80	.0	.0	.0	3.9	9.3	19.8	3.31	8.00	3.23	7.70		
70/57	.0	.0	.0	.0	1.3	16.9	.42	5.63	1.73	8.73		
40/57	.0	.0	.0	.0	18.8	23.6	6.52	7.92	13.15	11.64		
0/amb	.0	.0	.7	.0	11.3	.0	4.03	.00	12.50	.00		
std.dif.cans	------	1.62	1.21	5.25	14.06	12.32	8.15	7.79	------	------		
sign.dif.,5%	------	1.77	NS	NS	10.26	13.43	3.33	4.57	5.76[b]	7.90[b]		
mean,percent	.00	.31	.11	.63	8.79	12.42	3.03	4.46	2.35[c]	3.23[c]		

[a]Includes only seam which partially separated, not total seams.
[b]Significant difference for items in rooms.
[c]Significant difference for item means.

Seal Test. The seal test was a measure of linear separation of seams on a 1-inch cross section of bag when subjected to a steady 1-lb. pull for 5 minutes at 73°F/50% r.h. Data showing percentages of seams which partially separated, mean linear separation of these seams in inches, and percentages of seams which separated completely, for tests performed through 2 years and at 3-4 years, are listed in Table 17.

There was a decrease in partial separation during the last 2 years in all items, although mean separation per seal increased for the partially-separated seams of CD11 and CD13. Complete separation increased in all items, but remained very low in CD11 and CD12, in which most of both partial and complete separations were in bag seams from the higher temperatures. Thus CD13 was the only item in which defective seams increased significantly during the 3rd and 4th years, from 3.7% complete and 5.98% partial separation through the first 2 years to 12.42% complete and 4.28% partial separation during the last 2 years. Most of the separation in CD13 was at the 70° and 40°F conditions, but the only general statement which can be made concerning storage conditions effects is that total percent defective seams appears to be decreasing at 0°F.

Total defectives for 36-48 months were 1.47% for CD12, 6.28% for CD11, and 16.70% for CD13. Considering that CD13 seams averaged .044 inch wider, with only 1.0% under the standard .250 inch as compared to 9.6% and 4.9% under for CD11 and CD12, it would appear that the seaming of the CD13 bags was definitely not up to par.

2. Condition of Candy (Table 18)

Characteristics of the candies which were considered not likely to be affected by storage were not determined after the first year. These were:

	CD11	CD12	CD13	Mean
Product weight lbs.	34.2	35.8	34.0	34.7
Piece count per lb.	120	89	88	99
Count % per can, lemon	48.3	48.3	49.2	48.6
cherry	51.7	51.7	50.8	51.4
Unsanded, count %	.08	.21	.01	.10
Off-color, count %	.02	.01	.06	.03
Off-shape, count %	5.2	1.1	2.9	3.1

Characteristics which could be influenced by storage and handling were determined at every examination. Data on these for the 4-year inspections are shown in Table 18.

TABLE 18

PHYSICAL CONDITION OF CARBOHYDRATE SUPPLEMENT STORED 48 MONTHS

Condition °F/% r.h.	CD11	CD12	CD13	Mean	Std.dif. cans	CD11	CD12	CD13	Mean	Std.dif. cans
	Chipped Pieces[a], percent by count:					Pieces Stuck Together, per cent by count:				
0-36 mo.	3.38	14.44	6.11	7.98	3.38	1.73	.08	.65	.72	.79
100/80	6.3	13.8	12.2	10.80	2.86	3.3	.00	.8	1.37	1.80
100/57	3.7	13.5	11.2	9.46	1.44	1.4	.03	.5	.66	1.14
70/80	5.6	11.8	7.6	8.34	1.04	.2	.03	.1	.12	.09
70/57	3.9	22.4	9.9	12.07	1.39	1.4	.03	.2	.54	.21
40/57	4.0	18.8	7.8	10.19	1.76	2.3	.03	.9	1.06	.09
0/amb	5.9	19.4	8.3	11.18	1.73	.2	.03	.2	.13	.07
std.dif.,cans	1.67	2.25	1.35	1.80	------	1.50	.07	.20	.88	------
sign.dif.,5%	NS	1.95	1.17	1.09	2.66[d]	NS	NS	.18	.55	NS[d]
Mean	4.90	16.61	9.51	10.34	.98[e]	1.45	.03	.45	.64	.51[e]
	Pieces Broken Up[b], percent by count:					Material Passing 3-mesh[c], percent by weight:				
0-36 mo.	1.13	-.13	1.09	.70	.72	3.18	.59	.89	1.55	1.29
100/80	.1	.3	.4	.25	1.48	3.1	.5	.7	1.41	1.39
100/57	-.4	.1	1.1	.26	.84	1.9	.7	.6	1.06	.32
70/80	-1.0	.7	.7	-.33	.44	2.7	.6	1.0	1.44	.67
70/57	.0	.0	1.3	.44	1.07	2.3	.8	.9	1.31	.65
40/57	.3	-.2	1.2	.45	.39	2.2	.6	1.2	1.32	.65
0/amb	-.5	-.6	.7	-.13	.70	2.2	.7	1.1	1.33	.29
std.dif.,cans	1.24	.38	.86	.90	------	1.29	.13	.13	.75	------
sign.dif., 5%	NS	.34	NS	NS	NS[d]	NS	NS	.23	NS	NS[d]
Mean	-.25	-.18	.92	.16	.55[e]	2.40	.63	.90	1.31	.46[e]

[a]Pieces with not more than 25% broken off; reductions from normal weight for the three items averaged 25.2, 3.1 and 12.9%, respectively.

[b]Estimated as count in excess of amounts of chips required to restore chipped pieces to normal weight; negative values indicate chips discarded from chipped pieces before packing in the can.

[c]Most of this material was sanding sugar.

[d]Significant difference for items in rooms.

[e]Significant difference for item means.

Chipped pieces. These were defined as pieces from which bits of surface or corners were chipped off, but which remained at least 75% intact. With the exception that CD12 was high at 6 months (slightly damaged cases and cans were removed from storage early in the test), percentages of chipped pieces were higher at 4 years than at any previous examination. As periodic comparisons with previous highs averaged a 1.59% increase at 2 years, with additional increases of 1.35 at 3 years and 1.39% at 4 years, there appears to be a mean increase of about 1.4% chipped pieces per year since the end of the first year. This ranges from 0.9% for CD11 to 2.2% for CD12, and has been fairly consistent, so it seems reasonable to assume the increases reflect the effects of handling the supplement cases in storage and sampling.

There was apparently no temperature effect on chipping, nor were there any consistent differences between lemon and cherry types in CD11 and CD12. The cherry candy of CD13 chipped more than the lemon, however, in all except 2 of the 12 cans at 4 years, mean 11.6% vs 7.5%; from all cases of CD13 examined, chipping of cherry has been greater in 68% of the cans, averaging 7.4% as compared to 5.8% for the lemon type.

Broken pieces. These were defined as anything riding an 8-mesh screen which was less than 75% of a whole piece. They were calculated, however, as count % whole pieces in excess of amounts required to restore chipped pieces to normal weight. Thus the total count % values for chips actually present in the cans were the sums of values shown as chipped pieces and broken pieces in Table 18.

Averages for excess broken bits through three years were 1.01% for CD11, -0.17% for CD12 (chips apparently lost before the candy was packed in the cans), and 0.96% for CD13. These are very close to the 4-year means of Table 16 except in CD11; the only negative values observed for this item were those shown. There have been no consistent temperature or time effects, and no consistent differences between lemon and cherry types except in CD12, in which all lemon has averaged -.029%, all cherry -0.05% for excess bits. These also become meaningless, however, in comparison with the 15% mean amounts of bits which have been calculated as required to restore chipped pieces of CD12 to normal weight.

Pieces stuck together. As seen in Table 18, clumping of pieces was somewhat higher than previous average in CD11, slightly lower in CD12 and CD13. There was an association with can moisture within item CD11 (4 cans averaging 1.03% moisture had 0.20% clumps, 8 cans with 1.67% moisture had 2.07% clumps) but not between items, as CD12 had 1.49% moisture with almost no clumping, CD13 had 1.65% with only 0.45% clumps. Cherry candy had almost twice as much clumping as lemon in CD11, without association with moisture content, and lemon almost twice as much as cherry in CD13, but none of this followed any previously set pattern. For the three items, 77% of the clumped pieces were in clumps of 2 pieces (including all of CD12 and 96% of CD13), 11% in clumps of 3, 4% in clumps of 4, 2% in clumps of 5, with 1 clump (1%) of 11 pieces and 1 clump (5%) of 42 pieces; the 5, 11 and 42 clumps were in

TABLE 19

APPEARANCE-COLOR SCORES, MOISTURE CONTENT AND pH VALUES
FOR CARBOHYDRATE SUPPLEMENT STORED 48 MONTHS

Condition °F/% r.h.	CD11	CD12	CD13	Mean	Std.dif. cans	CD11	CD12	CD13	Mean	Std.dif. cans
	Appearance-Color Score, 10-1 scale:					Moisture Content, percent:				
Initial	8.36	8.24	8.20	8.27	.27	1.35	1.34	1.50	1.40	0.22
100/80	6.05	6.6	5.7	6.12	.97	1.65	1.40	1.64	1.57	.16
100/57	6.65	6.7	5.95	6.43	.54	1.39	1.48	1.68	1.51	.38
70/80	6.7	7.25	7.1	7.02	.13	1.02	1.53	1.52	1.36	.15
70/57	7.2	7.35	7.0	7.18	.13	1.85	1.51	1.71	1.69	.14
40/57	7.3	7.7	7.3	7.43	.47	1.80	1.49	1.73	1.67	.06
0/amb	7.4	7.7	7.35	7.48	.32	1.04	1.52	1.64	1.40	.05
std.dif.,cans	.24	.10	.85	.53	----	.31	.04	.11	.19	----
sign.dif., 5%	.42	.18	1.47	.47	NS[a]	.53	.07	NS	.17	.24[a]
Mean	6.88	7.22	6.73	6.94	.33[b]	1.46	1.49	1.65	1.53	.09[b]
	pH Values:									
Initial	6.55	6.65	6.75	6.65	.10					
100/80	5.95	6.45	6.53	6.31	.09					
100/57	5.86	6.44	6.46	6.25	.08					
70/80	5.56	6.70	6.50	6.25	.07					
70/57	6.12	6.35	6.55	6.34	.48					
40/57	6.07	6.11	6.55	6.25	.06					
0/amb	5.56	6.45	6.67	6.23	.10					
std.dif.,cans	.11	.34	.07	.21	-----					
sign.dif., 5%	.19	NS	.12	NS	.27[a]					
Mean	5.86	6.42	6.54	6.27	.10[b]					

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

CD11. With the exception that CD11 has had more clumps than CD13, and CD12 very few clumps at all, there is apparently no definite pattern to clumping of pieces other than increases in a few unsealed cans.

Material passing 8-mesh screen. With the exception that CD11 averaged lower than usual (initial 2.45%, 6-36 months 3.24%, 48 months 2.40%), sanding sugar and bits of candy passing 8-mesh was apparently not associated with any storage variable.

3. Appearance and Color (Table 19)

Sensory scores for appearance and color of the carbohydrate supplements stored 48 months were obtained from the five judges of the sensory quality panel in the same manner as described above for the cereal items. The two types of candy, lemon and cherry, were scored together, with separate comments when differences were present. In general, appearance was scored down for dullness and opaqueness, color for slight darkening and graying of lemon and slight fading of the cherry type. Scores in Table 19 are the means of appearance and color scores. CD11 scored slightly lower on appearance, CD12 on color, CD13 averaged the same for both attributes.

Scores were lower than on previous examinations for all samples except the 40° and 0°F candy of CD12. Mean reductions were 0.94 at 100°/80%, 0.43 at 100°/57% and the 70° conditions, 0.19 at the two lower temperatures. As seen from the large standard differences for duplicate cans, both color and appearance were quite variable in the candies from 100°/80%. The only two leakers detected, both from CD12, checked more closely than either CD11 or CD13, so the large can variance suggested the possibility of undetected leaking at this condition. In fact, the cans of both 100°/80% and 100°/57% in CD11 had marked differences in moisture content, although CD13 from 100° conditions was more variable in appearance-color scores with little variation in moisture.

Comments in general indicated that color had become quite variable, and somewhat unattractive in many samples, at 100°F, with some variability at 70° and slight loss of "brightness" at the lower temperatures.

4. Hunter Color Values (Tables 20 and 21)

Color values were determined on duplicate samples of 4-8 mesh bits of candy, cracked by hand to prevent "dusting" of surfaces. The Hunter Color Difference meter was set with NBS Maize (L = 73.8, a = 1.4, b = 31.4) for lemon candy, NBS Kitchen Red (L = 28.7, a = 49.5, b = 18.1) for cherry candy.

Hunter L Values. The extreme variability of the colors of some of the candies is illustrated by the L values for lemon type as given in Table 20. These averaged about 6.0 units higher than at 3 years, probably due to some difference in method of preparation of sample for making the readings --- general comments did not indicate this much fading of the candies. The

tendency to become duller at higher temperatures was indicated by differences in amounts of increase, however. The values for 100°F samples changed 1.8 units less, and those for 70° samples 0.5 less, than those for samples from 40° and 0°F.

The cherry type changed less in L values, mean changes from 3 years being a 2.1 unit increase for CD11 and a 1.2 unit decrease for CD12 and CD13. The slight fading effect at higher temperatures was illustrated by average changes, which were 0.7 increase at 100°F, no change at 70°, 1.0 decrease at the lower temperatures. Some of the panel judges noted a slight "darkened" appearance in the 40° and 0° samples in comparing them with samples from higher temperatures, although this is not too clearly indicated by the L values of Table 21.

Hunter "a" values. Changes in "a" values were fairly uniform in the lemon candies, averaging 0.3 unit decrease for CD11 and 0.7 unit increase for CD12 and CD13. For temperatures, changes from 3 years averaged 1.6 units increase at 100°, 0.4 unit increase at 70°, 0.8 unit decrease at 40° and 0°. As related to the values given in Table 20, these represent a slight shift from green toward gray for CD11 and CD13 and toward slight browning of the light pink of CD12 in samples from 100° and 70°F.

Values for "a" in the cherry type were somewhat more variable, as seen in Table 21, and there was an average increase over 3-year values of about 5 units in CD11, 4 in CD12, and 3 in CD13. The difference illustrating the slight fading at higher temperatures vs. slight darkening at lower, as mentioned by the taste panel, was the mean increase of 3.7 units at 100° and 70° vs. 4.8 units at 40° and 0°.

Hunter "b" values. The "b" values for lemon candies averaged 4.6 units higher, those for cherry candies 3.1 units lower than at 3 years. For the lemon type the increase averaged 4.1 at 100° and 70°, 5.3 at 40° and 0°F, indicating the duller or grayer shades at higher temperatures. The slight fading at 100°, or darkening at lower temperatures for the cherry type, as noted by some of the panel judges, was rather poorly indicated by the average decrease of 1.8 units at 100° vs. 2.1 units at 70° and below.

Hunter a/b values. The ratios of a/b given in Tables 20 and 21 indicate the predominant characteristics of the color of the various candies, i.e., the slight greenish-yellow of CD11 and CD13 as compared to the pink-yellow of CD12 lemon, and the paler red of CD12 cherry. They do not indicate the temperature differences, however, which could be seen by visual observation. These differences were suggested by the changes in a/b from the 3-year values, these being .059 increase at 100°F, .016 at 70°, and .023 decrease at 40° and 0° for the lemon type (i.e., grayer or darker at higher temperatures), and 2.13 increase at 100° compared to 2.43 at 70° and below for the cherry type (i.e., less red at 100° or less yellow at lower temperatures).

TABLE 20

HUNTER COLOR VALUES OF LEMON TYPE CARBOHYDRATE SUPPLEMENT STORED 48 MONTHS

Condition °F/% r.h.	CD11	CD12	CD13	Mean	Std.dif. cans	CD11	CD12	CD13	Mean	Std.dif. cans
	Hunter L:					Hunter "b":				
100/80	58.0	53.2	58.6	56.59	1.90	31.3	27.1	28.5	29.00	1.02
100/57	54.2	57.3	60.7	57.43	1.74	30.2	30.0	27.5	29.22	2.08
70/80	53.4	55.9	60.2	56.50	1.88	29.0	28.1	27.3	28.12	.68
70/57	57.2	57.0	60.8	58.35	3.69	30.9	29.8	29.6	30.11	2.51
40/57	58.0	57.1	57.6	57.59	3.79	32.4	28.5	28.1	29.63	.77
0/amb	53.9	56.2	59.1	56.38	.91	27.4	28.0	28.7	28.05	1.36
std.dif,cans	2.47	3.33	1.52	2.55	------	1.58	1.45	1.64	1.56	------
sign.dif.,5%	NS	NS	NS	NS	NS[a]	2.73	NS	NS	1.34	2.66[a]
Mean	55.80	56.11	59.50	57.14	1.54[b]	30.20	28.58	28.29	29.02	.95[b]
	Hunter "a":					Hunter a/b:				
100/80	1.3	10.2	-2.9	2.87	1.38	.041	.375	-.101	.045	.060
100/57	0.1	7.1	-3.6	1.18	.91	.001	.237	-.130	.018	.025
70/80	-0.1	6.6	-4.6	.61	.67	-.004	.234	-.169	.010	.023
70/57	-1.2	10.9	-4.3	1.81	.91	-.038	.368	-.147	.028	.042
40/57	-1.7	6.6	-5.3	-.16	.96	-.054	.233	-.191	-.002	.036
0/amb	-0.5	9.5	-3.9	1.71	.53	-.018	.341	-.137	.027	.037
std.dif.,cans	.53	1.33	.74	.93	------	.016	.056	.030	.038	------
sign.dif., 5%	.92	2.30	1.27	.80	1.48[a]	.028	.097	.051	.035	.061[a]
Mean	-.37	8.50	-4.12	1.34	.57[b]	-.012	.297	-.146	.046	.023[b]

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

TABLE 21

HUNTER COLOR VALUES OF CHERRY TYPE CARBOHYDRATE SUPPLEMENT STORED 48 MONTHS

Condition °F/% r.h.	CD11	CD12	CD13	Mean	Std.dif. cans	CD11	CD12	CD13	Mean	Std.dif. cans
	Hunter L:					Hunter "b":				
100/80	33.3	44.2	30.5	36.03	2.32	2.8	8.8	2.9	4.81	1.90
100/57	32.5	43.1	33.3	36.35	2.67	2.4	9.4	2.6	4.78	1.87
70/80	32.3	40.9	30.9	34.67	.70	2.0	9.8	2.7	4.83	.79
70/57	33.9	43.5	32.3	36.58	1.64	2.6	9.2	1.5	4.43	1.13
40/57	31.6	40.7	31.5	34.58	1.46	2.8	9.0	1.6	4.46	.51
0/amb	30.3	42.4	31.8	34.83	2.08	3.3	9.1	2.1	4.83	1.03
std.dif.,cans	1.04	2.82	1.40	1.92	------	1.16	1.58	1.16	1.31	------
sign.dif., 5%	1.80	NS	NS	NS	NS[a]	NS	NS	NS	NS	NS[a]
Mean	32.31	42.48	31.72	35.50	1.17[b]	2.64	9.21	2.22	4.69	.80[b]
	Hunter "a":					Hunter a/b:				
100/80	14.9	17.5	10.3	14.23	7.08	5.45	1.99	3.54	3.66	.38
100/57	11.9	20.0	7.1	13.00	6.20	4.90	2.14	3.25	3.43	1.61
70/80	8.0	20.6	10.6	13.10	1.96	3.95	2.11	3.97	3.35	.56
70/57	7.7	19.6	9.3	12.19	3.31	3.01	2.12	7.22	4.12	2.55
40/57	10.5	18.3	8.0	12.25	2.62	3.77	2.02	5.22	3.68	1.75
0/amb	14.0	19.8	8.9	14.23	3.77	4.25	2.18	4.57	3.67	2.06
std.dif.,cans	6.41	3.49	3.02	4.56	------	1.04	.15	2.70	1.68	------
sign.dif., 5%	NS	NS	NS	NS	NS[a]	NS	NS	NS	NS	NS[a]
Mean	11.16	19.31	9.03	13.17	2.77[b]	4.22	2.10	4.63	3.65	1.02[b]

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

In general, the Hunter color values remained, as at former examinations, a relatively poor measurement of changes which were readily observed by the taste panels. One of the chief reasons for this was that most of the changes were observed as surface and general appearance differences, whereas the Hunter instrument yielded values only for the center colors of the candy. The shifts caused by the effects of temperature were generally toward the gray or "neutral" region in lemon candies, and toward opaqueness and "purpling" of the red in cherry candies, and each of these are areas of poor response for tri-stimulus color measurements.

5. Moisture Content (Table 19)

Through 4 years, moisture has been determined as loss of weight on heating 20-mesh samples 24 hours at 65°-70°C with pressure about 30mm Hg, on lemon and cherry candies from 77 cans of each supplement item. CD11 averaged 1.62%, CD12 averaged 1.48%, with no mean difference between lemon and cherry; CD13 lemon averaged 1.75%, cherry 1.60%, with lemon higher in 49 of the 77 cans. In CD13, 48 cans ranged 1.6-1.9%, 22 cans 1.2-1.6%, 7 cans 1.9-2.1%. CD12 ranged 42 cans 1.5-1.7%, 23 cans 1.3-1.5%, 12 cans 1.1-1.3%. CD11, however, had 19 cans ranging 0.7-1.2%, 15 cans 1.2-1.6%, 25 cans 1.6-2.0%, and 18 cans 2.0-2.4%. This perhaps is a contributing factor in the wider ranges observed in almost all other characteristics of CD11.

As in the values given in Table 19, there has been no indication of any time or temperature effects on moisture levels. In most instances, as at 4 years, leaking cans have differed very little from non-leakers. Apparently moisture has varied only with formulation and cooking.

6. pH Values (Table 19)

pH values were determined with the customary glass-electrode pH electrometer, using 1 + 1 solutions of candy prepared with demineralized water. The values continued the downward trend which has been exhibited by all items since the end of the first year in storage. Compared to previous low values, the 4-year means were down 0.30 in CD11, 0.15 in CD12, 0.10 in CD13; mean decreases from initial values are shown in Table 19.

There was no consistent association with storage conditions, 70°/80% and 40°/57% averaging 0.24 decrease, other conditons 0.12 decrease. Lemon and cherry types did not differ significantly at 4 years. Leaking cans did not differ except in CD12 at 70°/57%, where the leaker was somewhat lower. In duplicate cans having moisture differences, the higher moisture and higher pH were usually found in the same can. As seen in the tabulated data CD13 had the smallest range of values, and CD11 the lowest values. In fact, CD11 was definitely low for the supplement type of candy, which probably contributed to the generally more variable quality of this item.

7. Sugar Contents (Table 22)

Sugars were determined by the official Lane-Eynon general volumetric procedure, with acid inversion at 73°F (Association of Official Agricultural Chemists, Washington, D. C.). Reducing sugar titrations were corrected for sucrose effect as directed by Fitelson (J. Assoc. Off. Agr. Chem., 1932, p. 624). All results were calculated on a dry weight basis.

Reducing Sugars as Dextrose. While reducing sugars did not average significantly lower at 4 years than on previous examinations, there were some unusually definite indications of changes associated with temperatures and pH values. For example, there were three samples with pH values lower than average: 70°/80% and 0°/amb in CD11 (pH 5.56) and 40°/57% in CD12 (pH 6.11, but 0.36 lower than other 5 samples). Reference to reducing sugar values in Table 22 shows that inversion is definitely indicated in the two low pH samples of CD11, and possibly in the 40°/57% sample of CD12. Although pH values were not particularly low, there was also some suggestion of inversion in the higher-temperature samples of CD13.

There were also some suggestions of decreased reducing sugars, possibly through anhydride formation and subsequent degradation reactions in some of the samples at higher temperatures. Examples were the 100°F samples of CD11 (1.1% below average), the 100°/57% and 70°/80% samples of CD12 (0.7% below average), and the 70°/57% sample of CD13 (0.9% below average); all of these also had low sucrose values.

Sucrose. There was little mean change in sucrose values with the exception of an 0.8% decrease from initial for CD13. (This item has averaged as high as initial on only one examination, however, so a reference value of 62.4% would probably be a better one than the initial 63.0% given in Table 22.) Differences among individual samples, as related to the changes in reducing sugars noted above, were observed as follows:

For the three samples in which inversion was suggested by high reducing sugars with low pH, sucrose averaged 4.1% low in the 70°/80% sample and 2.1% low in the 0°/amb sample of CD11. It was not low, however, in the 40°/57% sample of CD12. In CD13, with some inversion suggested at 100°F and possibly at 70°/80%, sucrose was 1.7% low at 100°/80%, but only slightly low or normal at 100°/57% and 70°/80%.

For the samples in which possible degradation of sugars was suggested, sucrose was 1.6% below average in CD11 at 100°/80%, but about average at 100°/57%; 1.7% below average in CD12 at 70°/80% but only 0.5% low at 100°/57%; and somewhere around 1% low in CD13 at 70°/57%. On the other hand, values were 2% above average in CD11 at 70°/57% and 40°/57%, with some increase in CD12 at 40°/57% and CD13 at 0°/amb, so definite statements concerning reduction of sugars through degradation may be questionable.

Total Sugars. Although the total sugar values for CD11 appear to average low as given in Table 22, the previous storage mean for CD11 was 80.9% instead of the 82.2% initial value shown, so there was actually no significant

TABLE 22

SUGAR CONTENTS OF CARBOHYDRATE SUPPLEMENT STORED 48 MONTHS

Condition °F/% r.h.	CD11	CD12	CD13	Mean	Std.dif. cans	CD11	CD12	CD13	Mean	Std.dif. cans
	Dextrose, percent:					Sucrose, percent:				
Initial	19.4	16.3	17.4	17.69	.41	62.8	65.1	63.0	63.63	.75
100/80	17.2	15.8	18.0	17.00	.52	61.1	65.0	60.7	62.26	1.48
100/57	16.7	15.5	18.3	16.84	1.45	62.6	64.6	62.1	63.09	2.23
70/80	20.6	15.5	17.8	17.93	.47	58.7	63.4	62.5	61.56	2.04
70/57	18.2	15.9	17.2	17.10	.77	64.8	65.1	61.7	63.85	1.53
40/57	19.3	17.2	17.5	18.00	.35	64.8	66.0	63.0	64.58	2.00
0/amb	20.4	16.6	17.5	18.17	.49	60.7	65.4	63.4	63.18	.64
std.dif.,cans	.91	.44	.86	.77	------	1.97	2.07	.94	1.74	------
sign.dif., 5%	1.58	.75	NS	.66	1.29[a]	3.40	NS	NS	1.60	2.87[a]
Mean	18.73	16.07	17.72	17.51	.47[b]	62.11	64.93	62.22	63.09	1.06[b]
	Total Sugar, percent:					Dextrose/sucrose ratio:				
Initial	82.2	81.4	80.4	81.3	.91	.309	.250	.277	.278	.007
100/80	78.3	80.8	78.7	79.26	1.73	.281	.243	.297	.273	.010
100/57	79.3	80.1	80.4	79.93	3.57	.267	.241	.294	.267	.015
70/80	79.3	78.9	80.3	79.49	2.20	.351	.244	.284	.291	.013
70/57	83.0	81.0	78.9	80.95	1.33	.282	.244	.279	.268	.017
40/57	84.1	83.2	80.5	82.58	1.75	.298	.260	.278	.279	.013
0/amb	81.1	82.0	80.9	81.35	.71	.336	.254	.276	.288	.009
std.dif.,cans	2.31	2.16	1.73	2.08	------	.017	.010	.011	.013	------
sign.dif., 5%	NS	NS	NS	1.44	NS[a]	.030	NS	NS	.012	.022[a]
Mean	80.84	81.00	79.94	80.60	NS[b]	.302	.247	.285	.278	.008[b]

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

decrease in mean values for total sugars. They averaged low, however, in CD11 at the 100°F and 70°/80% conditions (2.6%, 1.6%, and 1.6%, respectively), in CD12 at 100°/57% and 70°/80% (1.1% and 2.3%), and in CD13 at 100°/80% and 70°/57% (1.5% and 1.3%); as mentioned above, these decreases could represent degradation reactions. They could also be can fluctuations, as values 1.1% and 3.2% above average were found in CD11 at 70°/57% and 40°/57%, and CD12 at 40°/57% was 2% high.

Dextrose/Sucrose. Changes in ratios of dextrose to sucrose, as seen in Table 22, confirm the indication of inversion in CD11 at 70°/80% and 0°/amb, with possibility of inversion in CD12 at 40°/57% and in the 100°F and 70°/80% samples of CD13. Decreases were observed at 100°F and 70°/57% in CD11, with slight decrease in the 100° and 70° samples of CD12.

8. Sensory Scores for Texture, Aroma and Flavor (Table 23)

Scores were assigned by the 5-member sensory quality panel in the manner described above for cereal items (Section A. 3.).

Texture. As seen in Table 23, there was relatively little difference in texture scores for the various samples. Comments indicated the 100°F candies were scored slightly lower because of increased hardness or "toughness". The mean decreases from previous low scores were 0.13 for 100°, 0.34 for 70° and 40°, and 0.07 for 0°. As experience indicates that few members of this or the hedonic panel try to chew the candy, at least not until dissolving part of it in the mouth, the texture scores may be considered of little practical importance.

Aroma. The candies were scored low from 100°F for off or "terpene" odors, and reductions at 70° and 40° were attributed to "flatness" or lack of typical aroma. Scores seen in Table 23 averaged 1.6 lower than previously at 100°, 0.3 lower at 70°, about the same as previous lows at 40°. Candy from 0° was scored about the same as the average of all previous ratings, which was about 0.5 higher than the lowest ratings received during the first three years of storage.

Flavor. Candies from 100°F averaged 1.1 lower than previous lows because of off or "chemical, strong" flavors, with average reduction of 0.5 at 70° for slight off flavors or lack of typical flavor. Scores averaged 0.4 higher than previous lows at 40° and 0.5 higher at 0°, though 0.1-0.2 below previous averages at these temperatures.

9. Hedonic Ratings for Aroma, Flavor and Palatability (Table 24)

The hedonic evaluations of the supplements were made in the manner described above (Section A. 9.) for cereal items, several pieces of each of the two types of candy being presented as each coded sample.

Aroma. The aroma ratings given in Table 24 averaged 0.28 lower than previous low values at 100°F, 0.02 lower at 70°, but 0.18 higher at 40° and 0.44 higher at 0°. The 40° ratings averaged only 0.08 below initial,

TABLE 23

TEXTURE, AROMA AND FLAVOR SCORES OF CARBOHYDRATE SUPPLEMENT STORED 48 MONTHS
(Scale from 10 = excellent to 1 = poor)

Condition °F/% r.h.	Texture					Aroma				
	CD11	CD12	CD13	Mean	Std.dif. cans	CD11	CD12	CD13	Mean	Std.dif. cans
Initial	8.24	8.56	8.20	8.33	.17	7.4	7.6	7.8	7.59	.23
100/80	7.0	7.0	6.8	6.93	.47	3.8	4.4	5.0	4.40	.57
100/57	6.9	7.0	6.8	6.90	.42	4.4	4.7	5.1	4.73	.79
70/80	7.1	7.0	7.2	7.10	.12	6.1	6.4	6.7	6.40	.49
70/57	6.9	7.0	7.2	7.03	.26	6.3	6.5	6.7	6.50	.69
40/57	7.0	7.0	7.3	7.10	.12	6.7	7.5	7.3	7.17	.60
0/amb	7.3	7.0	7.3	7.20	.17	7.5	7.8	7.8	7.70	.12
std.dif.,cans	.44	.00	.26	.30	----	.72	.57	.44	.58	----
sign.dif., 5%	NS	NS	NS	NS	NS[a]	1.24	.97	.76	.50	NS[a]
Mean	7.03	7.00	7.10	7.04	NS[b]	5.80	6.22	6.43	6.15	.36[b]

	Flavor				
Initial	7.9	7.3	7.9	7.70	.24
100/80	4.9	5.1	5.4	5.13	.94
100/57	5.3	5.3	5.3	5.30	.69
70/80	6.3	6.8	6.7	6.60	.59
70/57	6.2	7.1	6.8	6.70	.35
40/57	7.2	7.5	7.4	7.37	.35
0/amb	7.3	7.7	7.9	7.63	.51
std.dif.,cans	.37	.44	.88	.61	----
sign.dif., 5%	.64	.77	1.52	.52	NS[a]
Mean	6.20	6.58	6.58	6.46	NS[b]

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

the 0° ratings 0.06 above initial. As with the smaller sensory quality panel, reasons given for reduction of ratings were predominantly off or "foreign" odors at 100° and lack of typical aroma at 70°.

Flavor. The flavor ratings at 4 years averaged 0.18 lower than previous low values at 100°F, but ratings at 70° averaged exactly the same as previous lows (CD11 decreased 0.28, CD13 decreased 0.08, CD12 increased 0.36). Flavor ratings for 40° candies averaged 0.36 above former low values and 0.46 below initial, while 0° ratings were 0.43 above previous lows and 0.44 below initial. As usual, reduction of ratings was caused by off flavors at 100° and lack of typical flavor at 70°.

Palatability. Ratings for palatability decreased more than aroma and flavor ratings after 4 years at 100° and 70°F, reductions from previous low values averaging 0.41 at 100° and 0.13 at 70°. Ratings at 40° averaged 0.19 above previous lows but 0.57 below initial, those at 0° were 0.41 above previous lows and 0.47 below initial.

Mean Hedonic Ratings. This section is included in Table 24 because it illustrates some of the characteristics of the carbohydrate supplements after 4 years in storage. It is seen that, while CD12 was rated lower than the other candies on initial examination for having less character, it changed less in storage at every condition. This item has been relatively stable in all characteristics. Second in general stability is CD13, which averaged higher than the other items at 100° and 70°F but changed more than did CD12. CD11 was least stable at higher temperatures, but changed less than CD13 at 40° and 0° conditions.

The differences in ratings between duplicate cans within the various samples is of some interest. As seen in Table 24, this difference was considerably larger in CD12, and in the lower temperature conditions. While there was a normal amount of variation in CD12, the only characteristics in which it varied more than the other items were chipped pieces, Hunter L values, and sucrose content. As described in Section A. 9., the panel members rated duplicate cans on different sessions, each session being one set of the six storage conditions. Comments indicated the unusually large can variation resulted from less distinct differences among conditions in CD12, causing the panel members, who expected differences among samples from past experience, to use relatively greater ranges of scores for smaller differences in this item. As these smaller differences tended to be more closely associated with variations among individual pieces of candy than among storage conditions in many instances, the result was an apparently large can variation when the two sets of ratings for CD12 were compared.

The same type of "comparison phenomenon" apparently caused the large can variations at 40° and 0°F. The differences in ratings resulted more from varying differences between 40° and 0° samples and those from 70° and 100°, which were compared within sets of samples, than from differences between the duplicate cans themselves. These, being presented in different sets, could not be directly compared.

TABLE 24

HEDONIC RATINGS FOR CARBOHYDRATE SUPPLEMENT STORED 48 MONTHS

Condition °F/% r.h.	CD11	CD12	CD13	Mean	Std.dif. cans	CD11	CD12	CD13	Mean	Std.dif. cans
	Aroma:					Flavor:				
Initial	6.88	6.76	7.04	6.89	----	7.76	7.24	7.76	7.59	----
100/80	5.30	5.88	6.05	5.74	.31	6.08	6.35	6.23	6.22	.15
100/57	5.60	5.73	6.35	5.89	.16	5.98	6.28	6.50	6.25	.13
70/80	6.38	6.55	6.40	6.44	.30	6.58	6.90	6.53	6.67	.19
70/57	5.98	6.50	6.60	6.36	.55	6.28	6.93	6.88	6.69	.52
40/57	6.65	6.90	6.88	6.81	.23	7.08	7.30	7.00	7.13	.38
0/amb	6.95	6.88	7.03	6.95	.13	7.20	7.08	7.18	7.15	.22
std.dif.,cans	.21	.45	.21	.31	----	.20	.46	.11	.30	----
sign.dif., 5%	.36	.78	.36	.27	NS[a]	.34	NS	.19	.26	NS[a]
Mean	6.14	6.40	6.55	6.37	.19[b]	6.53	6.80	6.72	6.68	.18[b]
	Palatability:					Mean Hedonic Ratings:				
Initial	7.48	7.40	7.76	7.55	----	7.37	7.13	7.52	7.34	----
100/80	5.73	6.18	6.10	6.00	.16	5.70	6.14	6.13	5.99	.21
100/57	5.80	6.15	6.30	6.08	.10	5.79	6.05	6.38	6.07	.13
70/80	6.53	6.73	6.33	6.53	.18	6.50	6.73	6.42	6.55	.23
70/57	6.15	6.73	6.68	6.52	.45	6.14	6.72	6.72	6.52	.50
40/57	6.90	7.18	6.90	6.99	.32	6.88	7.13	6.93	6.98	.31
0/amb	7.18	7.05	7.03	7.08	.18	7.11	7.00	7.08	7.06	.18
std dif.,cans	.18	.35	.21	.26	----	.20	.43	.18	.29	----
sign.dif., 5%	.31	.61	.38	.22	NS[a]	.17	.37	.16	.14	.27[a]
Mean	6.38	6.67	6.55	6.53	.16[b]	6.35	6.62	6.61	6.53	.10[b]

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

TABLE 25

CORRELATIONS OF PALATABILITY RATINGS AND OTHER MEASUREMENTS
FOR CARBOHYDRATE SUPPLEMENT STORED 48 MONTHS
(simple correlation coefficient, r)

	Lemon Type				Cherry Type				Combined Products			
	CD11	CD12	CD13	All	CD11	CD12	CD13	All	CD11	CD12	CD13	All
Palatability with:												
Hunter L	-.158	+.458	-.313	+.005	-.696[a]	-.381	-.222	+.087				
a	-.599[a]	-.171	-.478	+.065	-.124	+.017	-.184	+.087				
b	-.346	+.019	+.358	-.193	+.147	-.138	-.572	+.155				
a/b	-.613[a]	-.245	-.394	+.067	-.368	+.347	+.435	-.069				
Moisture	-.339	+.826[b]	+.322	-.084	-.294	+.373	-.098	-.137	-.317	+.566[b]	+.136	-.109
pH	-.262	-.568	+.037	-.019	-.460	-.366	+.750[b]	+.049	-.343	-.466[a]	+.436[a]	+.015
Dextrose	+.771[b]	+.089	-.273	+.111	+.826[b]	+.632[a]	-.132	+.267	+.792[b]	+.413[a]	-.208	+.189
Sucrose	+.142	-.043	+.284	+.179	-.237	+.686[a]	+.859[b]	+.277	-.072	+.338	+.562[b]	+.231
Total Sugar	+.577[a]	-.016	+.084	+.225	+.164	+.708[b]	+.857[b]	+.383[a]	+.365	+.381	+.376	+.308[b]
Dextrose/ Sucrose	+.628[a]	+.178	-.460	+.033	+.686[a]	+.366	-.547	+.113	+.657[b]	+.276	-.499[a]	+.074
Sensory Color									+.827[b]	+.915[b]	+.769[b]	+.750[b]
" Texture									+.328	.000	+.588[a]	+.321
" Aroma									+.865[b]	+.947[b]	+.829[b]	+.871[b]
" Flavor									+.920[b]	+.890[b]	+.710[b]	+.828[b]
Moisture with:												
pH	+.776[b]	-.344	+.061	+.485[b]	+.748[b]	-.468	+.033	+.461[b]	+.760[b]	+.076	-.100	+.472[b]
Dextrose	-.473	-.102	-.464	-.305	-.579[a]	+.069	-.228	-.404[a]	-.522[b]	+.052	-.258	-.353[b]
Sucrose	+.397	-.284	-.270	+.035	+.560	+.172	-.147	+.233	+.474[a]	-.021	-.136	+.134
Total Sugar	+.059	-.257	-.395	-.142	+.320	+.149	-.238	+.012	+.179	-.001	-.067	-.065
Dextrose/ Sucrose	-.583[a]	+.076	-.388	-.305	-.682[a]	-.033	-.064	-.470[b]	-.632[b]	+.099	-.174	-.384[b]

(continued)

Table 25 (continued)

	Lemon Type				Cherry Type				Combined Product			
	CD11	CD12	CD13	All	CD11	CD12	CD13	All	CD11	CD12	CD13	All
pH with:												
Dextrose	-.360	+.218	-.139	-.524[b]	-.636[a]	-.561	-.073	-.741[b]	-.467[a]	-.283	-.160	-.631[b]
Sucrose	+.714[b]	-.069	-.252	+.291	+.689[a]	-.548	+.779[b]	+.025	+.670[b]	-.316	+.287	+.149
Total Sugar	+.397	-.009	-.240	-.036	+.434	-.583[a]	+.794[b]	-.341[a]	+.402	-.326	+.169	-.198
Dextrose/ Sucrose	-.593[a]	+.401	-.016	-.580[b]	-.774[b]	-.366	-.455	-.661[b]	-.663[b]	-.105	-.294	-.620[b]

[a]Significant at the 5% level of probability.
[b]Significant at the 1% level of probability.

cereal item cases at 5 years. Reductions at 70° averaged 20 psig, but there was an average increase of 47 psig at 40° and 0°F. Values were below 400 psig in 84% of the cases at 100° (23% were below 300) and 31% of those at 70°.

2. Moisture content of the fiberboard averaged 11.0% at 80% r.h., 8.0% at 57% r.h., and 14.2 at 0°F with ambient r.h. Bursting strength was not significantly correlated with moisture content.

3-4. General condition of cases remained satisfactory. Despite reduced bursting strength at higher temperatures, there was no can collapse and relatively little distortion of cases, essentially no molding or delamination, only moderate staining, and practically no change in legibility of case markings.

II. Metal Cans

1. Residual oxygen in non-leaking cans of cereal rations averaged 3.7% at 100°F, 8.7% at 70°, 13.0% at 40°, and 17.7% at 0°, with considerable ranges at all conditions except 0°.

2. All cans leaked in one item (2½-gallon) and leakers ranged 8-25% in five others. Questionable leakers, ranging 4-33%, averaged 15% in ten items, leaving only one item free of leakers of any type.

3. Corrosion increased during the fourth and fifth years of storage on cans at the 80% r.h. conditions, with 10-20% of external surfaces corroded along seams and on panels. Internal corrosion remained practically unchanged, relatively slight. No leaks have been caused by corrosion.

4. Coatings of some of the 5-gallon cans were slightly yellowed at higher temperatures, but there was no softening or excessive flaking of any coating.

III. The Rations

A. Cereal Items.

1. Broken packages averaged about 5% higher than on previous examinations, the increase being 1% more broken seals and 4% more torn wrappers. One biscuit in waxed paper had no broken packages, wafers averaged 3.2%, other items ranged 8.3 - 43.8%.

2. Broken score lines ranged 1.2 - 24.5%, mean 11.2%; moderate unit breakage 0.1 - 25.3, mean 8.4%; severe breakage was negligible. Total breakage, 3.6 - 42.9% with mean 19.4%, was apparently not associated with storage time or temperatures.

3. Appearance-color sensory scores decreased about 0.4 during the fifth year, due to slightly increased glazing of surfaces at lower

temperatures and the apparent beginning of browning or darkening at 100° and 70°F. Most of the changes were in light-baked items, and all ratings still averaged "good".

4. Slight to moderate decreases in Hunter Color "L" and "b" values, with corresponding increases in "a" and a/b, were correlated with observed changes in appearance. Items at 100° and 70°F were generally lighter than initial, but darker than at periods of maximum fading.

5. Fracture strength ranged 1100 - 2300 grams by items, and was apparently related only to degree of baking or other item characteristics.

6. Moisture content ranged 1.5 - 3.5%, mean 2.5%, in crackers and biscuits; mean 3.9% in wafers. Moisture varied somewhat with degree of browning in baking, but was not significantly correlated with fracture strength.

7. Peroxide values ranged 1.8 - 3.7 m-eq., mean 2.9 at 0°F; 2.7 - 9.9, mean 5.4 at 40°; 2.7 - 25.7, mean 11.8 at 70°; and 1.5 - 34.8, mean 10.9 at 100°. General patterns indicated stability was exhausted at 100° and significantly decreased at 70°. Free fatty acids, ranging from 0.11 - 0.56, mean 0.27% at 0°F to 0.25 - 1.24, mean 0.70% at 100°, exhibited little indication of increase with storage. Free fatty acids have apparently established relatively steady-state b nces with oxidation in the various items at the various temperatures

8-9. Sensory quality ratings for texture still averaged "good", with moderate reduction for increased toughness or brittleness at higher temperatures. Scores for aroma and flavor and hedonic ratings for aroma, flavor and palatability were highly correlated. Palatability ratings ranged 2.55 - 4.45, mean 3.47 at 100°F (wafers and one cracker averaged 4.33); 4.63 - 6.10, mean 5.39 at 70°; mean ratings were 5.78 at 40° and 6.05 at 0°. The period of acceptable storage at 100°F is apparently passed, except possibly for wafers, which changed relatively little during the fifth year.

10. Correlations of palatability ratings with measurements associated with oxygen, rancidity, and color were relatively high.

B. Carbohydrate Supplements

1. Candy bags changed very little with storage except increases from 2.5 to 4.3% in partial separation and 4.5 to 12.4% in complete separation of seams in tests for one item.

2. Chipping of pieces of the hard candies appeared to be increasing by about 1.4% per year; the 4-year average was 10.3% chipped. Additional breakage, 0.2%; clumping, 0.6%; and loose sanding sugar, 1.3%, were apparently not influenced by storage.

3. Appearance-color scores averaged about 1.2 lower at 100°F and 0.4 lower at 70° than at the lower temperatures. Scores were reduced for opaqueness, with slight darkening or graying of lemon candy and slight fading of cherry candy.

4. Hunter Color values failed to show color differences which could be visually observed, as most changes were in areas in which the Color Meter is relatively insensitive.

5. Moisture contents averaged about 1.5% in two items, with considerable can variation in one; the third item averaged 1.65% with lemon candy about 0.15% higher than cherry. Storage has apparently not influenced moisture content except in a few leaking cans.

6. pH values averaged about 5.9 in one item, 6.5 in the other two. One item varied considerably among cans, another varied among storage conditions. The mean of 5.9, about 0.7 below initial, is considered low for the supplement type of hard candy.

7. Dextrose contents averaged 16.1, 17.7 and 18.7%, with corresponding sucrose averages of 64.9, 62.2 and 62.1%. There was definite indication of inversion in two samples with pH below 5.6, and possible inversion in four other samples with pH nearer normal. Five samples, all at higher temperatures, were below average in both dextrose and sucrose, suggesting that degradation reactions may have accompanied observed changes in color and crystal structure of these candies.

8-9. Texture scores varied little, and were relatively unimportant, as few persons attempt to chew the hard candy before partially dissolving it in the mouth. Quality and hedonic ratings for aroma ranged 0.2 - 1.0, mean 0.55 lower than those for flavor of candies from 100°F, and averaged 0.25 lower at 70°; mean hedonic ratings were 6.03 at 100°, 6.53 at 70°, 7.02 at lower temperatures. Thus, although the candy was definitely off-color at 100°, it was still rated moderately good to eat.

10. Correlations of palatability ratings with other measurements were generally inconsistent. The supplement apparently lacks a related sequence of changes such as the temperature-fading-oxidation-rancidity pattern of the cereal items.

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13. ABSTRACT

Results are reported on the stability of ten lots of fallout shelter cereal rations stored for 5 years and 3 lots of carbohydrate supplement stored for 4 years at 100°F/80% r.h., 100°/57%, 70°/80%, 70°/57%, 40°/57%, and 0°/ambient r.h. Rations include 4 lots of survival crackers, 4 lots of survival biscuits, 2 lots of bulgur wheat wafers, and 3 lots of mixed lemon and cherry flavored hard candies. Data include 60-month and 48-month values, respectively, for (1) bursting strength, moisture content, and general conditions of V3c fiberboard cases; (2) residual oxygen, leaking, corrosion, and coating defects of 2 1/2-gallon and 5-gallon metal cans; (3) breakage and general condition of package seals, seams, materials, and product units; (4) fracture strength, peroxides, and free fatty acids of wheat products; (5) pH and sugar contents of carbohydrate supplements; and (6) moisture content, color, sensory quality, and hedonic ratings for all products. Results of previous examinations of stored rations are discussed.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Storage stability	8					
Cans	9					
Fiberboard	9					
Containers	9					
Food containers	9					
Rations	4		4			
Survival	4		4			
Civil Defense	4		4			
Shelters	4		4			
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